This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

MATTER:

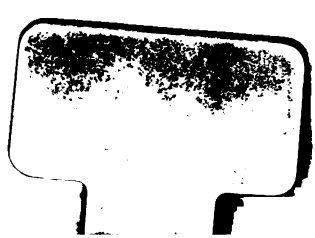
ITS

FORMS AND GOVERNING LAWS.

BY

GEORGE DUPLEX.

Price 3s. 6d. With Illustrations.



MATTER:

ITS FORMS AND GOVERNING LAWS.

MATTER:

ITS

FORMS AND GOVERNING LAWS.

BY

GEORGE DUPLEX.

WITH NUMEROUS ILLUSTRATIONS ON WOOD.

LONDON:
BRADBURY & EVANS, 11, BOUVERIE STREET.
1857.

193. c. 13.

LONDON:
BRADBURY AND EVANS, PRINTERS, WHITEFRIARS.

PREFACE.

THE following pages are put forth in the hope they may be found useful to that class of readers whose early studies may not have been directed to the subjects upon which they treat. Many, so circumstanced, are often prevented from commencing the study of what are termed the Natural Sciences, from the apparent difficulties so vast a subject presents, and perhaps also from not knowing how to avail themselves of the rich stores of knowledge within their reach. To such, these pages will be found to stand in the relation of an index to the elaborate works wherein the separate divisions of the various subjects are treated with lengthened detail. In these pages, a mere general idea has been given, divested of fatiguing details, so linked, that the natural and mutual relation of the sciences to each other may be readily comprehended and viewed as a whole. It will be thus seen that the infinite modi-

fications and adjustments of all created matter—in the greatest as in the least—are dependent upon few and simple laws, constant and universal in their action.

It is hoped that this general idea, when perfectly understood, may lead to a further and more profound study of the whole subject.

At the conclusion of each section, a reference will be found to the works of those authors who have been taken as authorities upon the given subject.

TORRINGTON SQUARE,
November, 1856.

CONTENTS.

	PAGE
PRELIMINARY DEFINITIONS OF MATTER	1
BODIES OF MATTER MOVING IN SPACE	3
GOVERNING LAWS OF THE BODIES IN SPACE	15
TERRESTRIAL MATTER	22
HEAT	23
LIGHT	26
ELECTRICITY	27
MAGNETISM	29
LAWS OF ATTRACTION AND AFFINITY	33
CHEMISTRY OF THE ELEMENTARY SUBSTANCES	35
PRIMARY FORMATION OF THE TERRESTRIAL FORMS OF MATTER	51
TERRESTRIAL INTERNAL HEAT	56
VITALIZATION OF MATTER	69
VEGETATION.—THE VEGETABLE KINGDOM	70
VEGETAL NUTRITION	77
REPRODUCTION	82
VEGETABLE CHEMISTRY	91
ANIMALIZED MATTER	102

PAGE

ANIMAL NUTRITION 119

REPRODUCTION 121

INTELLIGENT AND INTELLECTUAL MATTER 124

HUMAN INTELLECTUAL MATTER 128

HUMAN ORGANS OF NUTRITION 134

NUTRITION 144

ORGANS OF EXTERNAL SENSATION, OR PERCEPTIVE ORGANS 145

ORGAN OF VOICE 150

INTELLECTUALITY 151

MEMORY 152

VOLITION 152

THOUGHT 153

REASON 155

PASSIONS 156

EMOTIONS 157

SLEEP 158

DEATH 159

HEALTH 159

MATTER:

ITS FORMS AND GOVERNING LAWS.

PRELIMINARY DEFINITIONS.

1. THE term *Matter* is understood to be the entire aggregate of substances, as well as their minutest divisions, that compose the universe.

2. The properties of matter are general and particular. The general are, extensibility, impenetrability, mobility, divisibility, porosity, and indestructibility.

3. By *extensibility* is meant the property of occupying a certain portion of space: a substance is said to be extended when it possesses length, breadth, and thickness.

4. By *impenetrability* is meant that no two portions of matter can occupy the same portion of space at the same moment.

5. By *mobility* is meant the capacity of motion; for though matter is susceptible of rest and motion, it has no inherent power either of beginning to move when at rest, or of arresting its own progress when in motion; it is, therefore, in itself perfectly passive.

6. By *divisibility* is meant the capacity of separation of its particles. Matter is divisible to an extreme degree of minuteness. It consists of ultimate particles, so small as not to admit of further division. These

ultimate particles have received the name of atoms, and to each atom (with the exception of further divisibility) is ascribed the properties common to the whole mass.

7. The minute particles which make up an entire body only touch each other at a few points. This arrangement is called *porosity*. A substance being expanded or diminished in bulk is the result of the particles receding from or approaching each other more closely. In the atoms themselves no change can take place; when, therefore, the intervening spaces are manifest, the substance is termed *porous;* when the particles, on the contrary, closely approximate, the substance is then termed *dense*.

8. By *indestructibility* is meant that matter never ceases to exist. To our common apprehension, coals and wood, being burned, are destroyed; water and other fluids in evaporation are lost; such is not the truth:—the particles forming the wood, coals, water, &c, are only by the operation of heat changed in their relative positions to each other, and no longer confined to these particular forms, are set free to recombine in others; hence the exact quantity of matter combined to form the earth in the first instance, is now the same in quantity to a single particle.

9. The *particular* properties of matter depend upon the arrangement and combination of its atoms, and it has, therefore, either the property of hardness, softness, elasticity, colour, density, fluidity, and solidity; it is also either organic or inorganic, that is, with or without life.

10. Matter, in its aggregation and in its particles, is subject to, and invariably obeys, certain laws that govern all its relations. These laws have been grouped together, and such groups severally termed Astronomy, Chemistry, Physiology, &c.; but though these groups have always in a great degree been isolated, and treated as distinct sciences, they are, never-

theless, intimately associated, and no one of the subjects so designated can be rightly understood, without a clear understanding of the others, inasmuch as their governing laws are few in number and antagonistic.

BODIES OF MATTER IN SPACE.

11. The heavens present an innumerable multitude of material objects which are called generally by the name of stars. Observation informs us that some of these are constantly changing their relative places in the heavens, and that others have the appearance of permanence; the latter, therefore, have been called *fixed stars*, while the former are termed *planets*, or wanderers. The term *fixed*, however, must be understood in a comparative and not an absolute sense, it being certain that all the heavenly bodies are in a state of motion. For convenience, perhaps, the ancients, in reducing Astronomy to a science, formed the stars into constella tions or collections of stars, and represented them by animals and other figures, according to the fanciful ideas the dispositions of the various groups of stars suggested. This arrangement took place very early, for some kind of division or classification became necessary, in order that astronomers might describe any particular star so as to be understood. Neither without some such division could the situation of the planets be pointed out, as they are continually changing their places. Astronomers divide the heavens into three regions—the northern and southern hemispheres, and the zodiac; the last is the area in which the apparent motions of the sun, moon, and planets are confined. Astronomers also distinguish the stars into classes according to their apparent brightness. These are termed magnitudes. The brightest stars are said to be of the first magnitude, those which fall so far short of the first degree of

brightness as to make a strongly marked distinction, are classed in the second, and so on down to the sixth and seventh, which comprise the smallest stars visible to the naked eye in the clearest and darkest night;—beyond these, telescopes continue the range of visibility, and magnitudes, from the eighth down to the sixteenth, are familiar to those who are in the practice of using powerful instruments, but there is no reason why any limit should be assigned to this progression, every increase in the dimensions and power of instruments which successive improvements in optical science have obtained having brought into view multitudes of objects invisible before. This classification is entirely arbitrary, but usage has established it, and though it is impossible to determine where one magnitude ends and the next begins, yet on the whole astronomers have restricted their first magnitude to about 24 principal stars; their second to 60 next inferior; their third to about 200 yet smaller, and so on; the numbers increasing very rapidly as we descend in the scale of brightness. The whole number of stars already registered down to the seventh magnitude, inclusive, amounting to about 15,000.

12. The Zodiac is an imaginary circle surrounding the heavens, in which the sun and planets appear constantly to revolve. It is divided into twelve constellations or signs; the first six are called northern, the others the southern signs. The uncouth figures of men and monsters, which have served to designate these signs, and laid down in globes and maps, are disregarded by astronomers; and only named by them in conjunction with remarkable stars, attaching a Greek alphabetical letter to distinguish the magnitude, as α Leonis, β Scorpio, &c.

13. There is, besides, a natural district in the starry heavens, offering a peculiarity of character that strikes every observer; this is the Milky-way (or Galaxy, as it is

termed by astronomers), stretching across the sky, and when traced is found to form a zone encircling the whole sphere. This remarkable belt has apparently from the earliest ages maintained the same relative situation among the stars; and when examined through powerful telescopes, is found to consist entirely of stars, scattered by millions, like glittering dust, on the black ground of the heavens. The mode in which these stars are scattered over the Milky-way is very irregular; thickly strewn in some places, thinly scattered in others; while in some spots hardly a single star is to be found.

14. The appearances and circumstances in which we view these multitudes of so-called fixed stars are not always the same: some appear periodically, as if they were subject to orbitual motion; some have appeared suddenly shining brightly for a short period and then disappearing entirely. Many of them when examined by telescopes, are found to be double, *i. e.*, to consist of two (in some cases three or more) individuals placed near together. Many of these appear to revolve about each other in distinct orbits. Great difference of colour is also observable between them; white, yellow, red, blue, and green being frequently presented to the eye in contrast; but whether this be real or an optical effect is somewhat doubtful.

15. The proper motions of the stars must, of course, be inconceivably difficult to arrive at: it might be expected that apparent motions of some kind or other should be detected among so great a multitude of individuals scattered through space, and with nothing to keep them fixed; and it is a fact, that such apparent motions are really proved to exist by the exact observations of modern astronomy.

16. The distances of the fixed stars are enormous; the nearest to us, Sirius, the dog-star, is two billions of miles, *i. e.*, two millions of millions of miles. A rail-

way engine travelling at the rate of 100 miles an hour, would take 2,283,653 years to reach it.

17. Certain spots or districts, termed *Nebulæ*, are also observed in the heavens, which to the naked eye appear as white filmy clouds, but powerful telescopes resolve them into clusters of innumerable stars; and as the perfection of instruments has advanced, so have further nebulosities been resolved into their component stars; but others still exist, that even the powerful telescope constructed by Lord Rosse, has failed to resolve into distinct stars.

18. Observations have led astronomers to conclude that these multitudes are distinct systems of stars or suns, with their revolving planets, although invisible to any telescopic power;—and that these solar systems again make up distinct astral systems, which move in harmony with the whole sidereal system in space; our own solar system being placed near the edge of one of these astral systems and moving with it.

19. In this great sidereal system our own sun, with its revolving planets, forms a unit. Its form is that of a sphere; its diameter, 882,000 miles; its distance from the earth, 95,000,000 miles. When viewed through powerful telescopes, the sun is observed to have large and perfectly black spots upon it, surrounded with a kind of border less dark. They are not permanent; when watched from day to day, or even from hour to hour, they appear to enlarge and contract, to change their forms, and at length to disappear altogether. As they change and break up, they offer every evidence of that extreme mobility which belongs only to the fluid state; and of that violent agitation, which seems only compatible with the atmospheric, or gaseous state of matter. They seldom last longer than six weeks. It appears probable that these spots are the dark solid body of the sun itself, laid bare to our view

by those immense fluctuations in the luminous regions of its atmosphere to which it appears to be subject.

The sun has two motions: one direct in its sidereal path,—the other a revolution upon its axis, which is completed in about twenty days. The sun advances through space, carrying with it its whole planetary and cometary system, with a velocity of 422,000 miles per diem, or 154,185,000 miles per annum.

20. Revolving round the sun at various distances are eighteen bodies called planets. These, with the sun, form what is termed our solar system. Of these planets, four,—Venus, Mars, Jupiter, and Saturn are remarkably large and brilliant; a fifth, Mercury, is also visible to the naked eye, but is seldom conspicuous; a sixth, Uranus, is barely discernible with a telescope; and ten others, Neptune, Ceres, Pallas, Vesta, Juno, Astræa, Hebe, Iris, Flora, and Metis, with one discovered by M. de Gasparis, are never visible to the naked eye. Mercury and Venus, revolving in orbits between the earth and sun, are termed inferior; the others, revolving exterior to the earth's orbit, are called superior planets.

The orbit of a planet is the circular path in which it travels round the sun.

21. The planet Mercury is the nearest to the sun; —his diameter is one-third that of the earth, or about 3200 miles. He revolves around the sun in 87 days, 23½ hours, at the distance of 36,000,000 miles; moving in his orbit at the rate of 109,360 miles per hour.

22. Venus is the second planet from the sun, and is easily distinguished by her superior brightness; her diameter is about 7800 miles. She revolves in her orbit in less than 225 days, with a rotation about her axis of twenty-four hours, at a mean distance of 68,000,000 miles, moving at the rate of 800,000 miles per hour. The orbits of these planets being within

that of the earth, causes them to be viewed with different phases like that of the moon, and there happens what is denominated the transits of Mercury and Venus, or the passing of their bodies over the sun's disc in the form of a dark round spot. With Mercury this rarely happens; and with Venus once in about ninety years.

23. The Earth is the third planet from the sun. Its diameter is 7970 miles, and its circumference above 25,000. Its distance from the sun, 95,000,000 miles. It has two constant motions, one about its axis, completing its rotation in 24 hours, forming our natural day; the other through its orbit round the sun, moving at the rate of 68,040 miles per hour, performing an entire revolution in 365 days, 5 hours, 48 minutes, and 49 seconds.

Hence the division of time into days and years is prescribed by the motions of the earth—the former depending upon the rotation of the earth upon its axis, the latter upon its revolution in its orbit.

The form of the earth is not that of an exact globe or sphere, but of a spheroid, *i. e.* a little flattened at the poles, having the diameter at the equator 30 or 40 miles larger than at the poles.

24. At a mean distance from the earth of 237,000 miles, and revolving round it in an elliptic orbit is a planetary body—the Moon—denominated a satellite. It moves in its orbit at the rate of 2290 miles in an hour, and completes her revolution in 27 days, 7 hours, 43 minutes, and 11 seconds. Its diameter is 2160 miles, and its bulk nearly a fiftieth part of the earth's. One side only is always exhibited towards the earth; the diurnal rotation on its axis being performed in the same time as the orbital revolution,—hence her day and night taken together are just as long as from one new moon to full moon. The moon accompanies the earth in its annual orbit, and during that period revolves

nearly thirteen times round the earth in its lunar orbit. The different forms of increase and decrease which she presents during the time of each revolution, are called her phases. Like the other planets, the moon is an opaque body borrowing her light from the sun, hence only that half which is turned towards him can be fully illuminated; the opposite half would remain in darkness were it not for the light reflected from the earth. Therefore, as the light of the moon visible on the earth is on that part of her body turned towards us, we shall, according to her different positions, perceive different degrees of illumination; hence she appears sometimes waning, sometimes horned, then half round, &c. The shades which appear on the face of the moon are found, when viewed through a telescope, to result from the diversity of mountains and valleys; when the moon is either horned or gibbous, the irregularity of her surface is clearly discerned by the border appearing indented or jagged, especially about the edge of the illuminated part. From exact calculations of their shadows, some of them have been found as high as 22,823 feet. The moon has no clouds, or other indications of an atmosphere. From the circumstance of the moon being the nearest planetary body to us, it necessarily eclipses every star or planet that shines upon us, including the sun. The character of the eclipse, whether total, partial, or annular, will depend upon the relative position of the moon in its orbit.

25. The orbit of Mars is next above that of the earth, and he is the first of the superior planets. He is known in the heavens by a dusky red appearance. His diameter is 4100 miles; distance from the sun, 144,000,000 miles; diurnal motion, 24 hours, 39 minutes. His orbital revolution makes the length of his year 687 of our days. Though Mars when viewed through a telescope appears mostly full, he is seen at times to increase

and decrease somewhat like the moon, with this exception, he is never horned.

26. Until the commencement of the present century, Jupiter was supposed to be the next planet to Mars, but owing to the distance being greater than the relative ones of Mercury, Venus, the Earth, and Mars, it was surmised by Professor Bode, of Berlin, as a thing not unlikely, that a planet not yet discovered might exist between Mars and Jupiter. The heavens being carefully watched, Ceres was discovered by Piozzi, at Palermo, in 1801; Juno by Professor Harding, of Gottingen, in 1804; Pallas and Vesta by Dr. Olbers, of Bremen, in 1802 and 1807; Astræa and Hebe by Professor Hencke, in 1845 and 1847; Iris and Flora by Mr. Hind, in 1848; and one not yet named by M. de Gasparis, in 1849. These, from their comparative smallness of size, have been called asteroids, and it has been conjectured that they are fragments of some greater planet which formerly revolved in that interval, but which has by some explosion separated into several portions.

Their distances from the sun vary from 237,000,000 to 300,000,000 miles. Their revolutions in their orbits from 4 years, 4 months, to 4 years, 8 months. Their diameters are not all known, but Ceres is calculated at 1761 miles; Pallas, 2280; and Juno at 1545 miles. The diurnal motion of Pallas is completed in 12 minutes 40 seconds.

27. Jupiter, the next and largest, distinguished also by his peculiar brilliancy, is in diameter 87,000 miles, and in bulk exceeds that of the earth nearly 1300 times. He is distant from the sun about 490,000,000 miles, travelling in his orbit at the rate of more than 25,000 miles an hour, he completes his annual revolution in 4332 days and a half, or nearly 12 of our years. His diurnal rotation upon his axis takes place in less than ten hours, at the amazing rate of 26,000 miles an hour,

a velocity 25,000 times greater than the earth's. His form is elliptical, as might be supposed from his great velocity, hence his equatorial is 6000 miles greater than his polar diameter; and as the variety of the seasons of a planet depends upon the inclination of its axis to its orbit, Jupiter having no inclination there can be no difference in his seasons, nor any variation in the length of his days and nights. When viewed through a telescope the disc of Jupiter is always seen crossed in one direction by dark zones or belts, varying in breadth and situation, though never in their general direction. It seems to be probable they exist in the atmosphere of the planet. Jupiter has four satellites revolving about him at different distances, and in different periods of time, the nearest making a revolution in less than two days, and the most distant in little less than sixteen; hence their relative situations change every instant.

28. The next in order of remoteness is Saturn, shining with a pale leaden light. His distance from the sun is nearly 900,000,000 miles. The light and heat he derives from the sun must therefore be ninety times less than that of the earth. His bulk is little less than that of Jupiter, his diameter being 79,000 miles. He performs his annual revolution in 10,759 days, being very nearly thirty of our years; consequently he must travel 21,000 miles an hour.

Fig. 1.

He revolves about his axis in 12 hours 13¼ minutes.

The body of Saturn is striped with dark belts, somewhat similar to Jupiter, but less strongly marked;

he is attended by seven satellites; the one nearest him performs a revolution in 22½ hours—the one most remote in 79 days, 7 hours.

A still more extraordinary appendage is to be found in the luminous rings that surround this planet. They consist of two broad, flat, extremely thin rings, concentric with the planet and with each other (fig. 1).

Their dimensions are as follows:—

Exterior diameter of exterior ring . .	176,418 miles.
Interior ditto	155,275 ,,
Exterior diameter of interior ring . .	151,690 ,,
Interior ditto	117,339 ,,
Interval between the planet and interior ring	19,090 ,,
Thickness of the rings	250 ,,

The ring has a rotation about its axis, or, which is the same thing, revolves about the planet in 10 hours, 32 minutes, 15 seconds.

29. The next planet is the Georgium Sidus, Uranus, or Herschell, as it has been severally called. He appears of a bluish-white colour, a uniformly illuminated disc, without rings, belts, or discernible spots. His diameter is about 35,000 miles, with a bulk eighty-two times that of the earth; his distance from the sun, 1,800,000,000 miles.

His orbital revolution is performed in about eighty-four of our years, consequently he travels at the rate of 16,000 miles an hour. His diurnal rotation has not been ascertained. He is attended by several satellites —certainly four, probably six. Their orbital motions present very remarkable differences to other planetary bodies, moving from east to west, instead of from west to east, as is the case with every other planet and satellite.

30. The discovery of Neptune is so recent, and its observation so unfavourable, that its physical character and appearances are still far from certain. It appears to be attended by one, and probably two satellites. The

second, however, is hardly yet demonstrated. Its distance from the sun is about 2,700,000,000 miles.

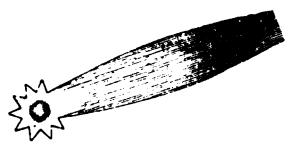
31. It is deserving of remark, that the discovery of Neptune was the result of pure astronomical calculation. Certain irregularities of the orbital motion of Uranus induced the suspicion that another planet existed beyond it, and Messrs. Adams of Cambridge, and Leverrier of Paris, simultaneously announced where it ought to appear in the heavens, if visible. Dr. Galle, of the Royal Observatory of Berlin, upon the receipt of this communication, turned his telescope on the spot, and found it within a single degree of the place assigned.

32. Besides these planetary bodies there are others revolving about the sun, not in circular orbits, but in extremely long elliptic curves, having the sun in one of their foci, approaching sometimes near the sun, at others stretching far beyond the orbit of the remotest planet. These bodies are called Comets, the name being derived from the word *cometa*, hairy, and given to them in consequence of their appearing with long luminous tails, somewhat resembling hair. The number of comets which have been observed or recorded in history is very great, amounting to some hundreds. Multitudes must, however, escape all observation, by reason of their paths traversing that part of the heavens which is above the horizon in the day time. Comets so circumstanced can only become visible by the rare coincidence of a total eclipse of the sun, a coincidence which happened sixty-two years before Christ, as related by Seneca, when a large comet was actually observed very near the sun.

Comets consist, for the most part, of a large and more or less splendid but ill-defined nebulous mass of light called the head, which is usually much brighter towards its centre, and offers the appearance of a vivid nucleus (fig. 2). From the head appear to diverge two streams

of light which grow broader and more diffused at a little distance from the head, and close in and unite at some distance behind it. This is the tail. This magnificent appendage attains occasionally an immense apparent length. It is, however, by no means an invariable appendage of comets; many of the brightest have been observed to have short and feeble tails, and a few great comets have been entirely without them. It is to be observed that the tail always appears, as it were, from the sun, the head, therefore, is always directed towards the sun, both in advancing and receding from it.

Fig. 2.



The physical structure of comets appears from all the evidences of observation to be something in the nature of a smoke, fog, or cloud, suspended in a transparent atmosphere; but what the nature of a comet really is, what is the cause and mode of its luminosity, is as yet a profound secret of nature. Their motions are also most irregular and capricious. Some move with extreme slowness, others with extraordinary velocity.

The orbit of some comets, as before observed, is an ellipsis, others are parabolic, that is, ellipses whose axes are of infinite length; so that a comet whose path is an ellipsis, however long its axis, must have visited the sun before, and must (unless disturbed) again return in some determinate period; but if its orbit be of a parabolic character, when once it has passed its perihelion (its nearest point to the sun), it could never return, but must run off to visit other systems, and be lost in the immensity of space. Great diversity obtains in the dimensions of comets; the tail of the great comet of 1680 was found by Newton to have been 120,000,000

miles in length; the comet of 1769 extended 48,000,000 miles; that of 1811 upwards of 100,000,000 miles. Their numbers circulating in space must be enormous, to be counted only by myriads.

33. Meteoric appearances take place in the heavens known familiarly as *shooting stars*, mostly lasting for a few moments only. These are conjectured to be fragments of planetary bodies, revolving in orbits of their own, but grazing the confines of our atmosphere; and this appears to be confirmed by the fact that large masses of meteoric metal have frequently fallen upon the earth, the origin of which it would be difficult otherwise to account for. On particular nights—the 9th and 10th of August, the 12th, 13th, and 14th of November, streams of meteors have been observed, and their periodic times tend further to the conclusion that they must be, as it were, a planetary dust circulating in orbits but little distant from the earth.*

GOVERNING LAWS OF THE BODIES IN SPACE.

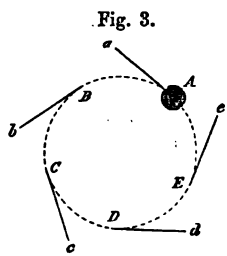
34. The Power, Force, or Law that controls the motions of the enormous masses of matter of which the heavenly bodies consist, is *Attraction* or *Gravity*. This is the first and most pervading of all natural laws, controlling by its influence the minutest molecules of matter, to the vast and stupendous globes hung in illimitable space. Every atom of matter has the tendency to approach to, and attract towards it, every other atom; and every two atoms or masses of matter would always and inevitably coalesce, were it not that certain resistances, the result of other *laws*, prevent it. "Material bodies attract each other with forces proportional to the quantity of matter they contain;" for example, if

* For further details the reader is referred to Sir Wm. Herschell's "Elements of Astronomy."

two masses of matter in motion, of equal weight and density, were to attract each other, they would meet at a point equidistant between them; but if one mass were three times the bulk of the other, then the lighter would move three times as far, and faster than the heavier, moving three feet while the heavier moved one. Also, the intensity of this force (attraction) is modified by distance, so that two bodies, at a distance of one foot, will be attracted to each other with a force four times the amount of intensity they would be at a distance of sixteen feet; and this law is expressed thus:—"Attraction decreases as the squares of the distances from the centres increase."

35. All simple motion is naturally rectilinear, that is, all bodies, if there were nothing to prevent them, would move in straight lines. When a stone is whirled round in a sling its motion is circular; when the stone escapes, it will go off in a straight line. This straight line is what is called the *tangent* of a circle.

Fig. 3.



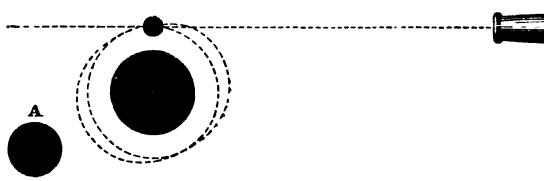
Suppose a body A, fig. 3, in the circular motion B, C, D, E, ceasing to be acted upon by the circular force at any one of the points B, C, D, E, it would immediately fly off in the straight lines A *a*, B *b*, C *c*, D *d*, E *e*. These two motions, therefore, are called *attractive* or *centripetal*, and *projectile* or *centrifugal* forces.

The knowledge of these laws enables us to comprehend the various motions of the heavenly bodies, and their apparent diversities. The joint or rather antagonistic actions of the attractive and projectile forces, retain the planets in their orbits;—the primaries round the sun, and the secondaries or satellites round their pri-

maries. But from the many opposing attractive forces in action, their orbits are rendered elliptical instead of circular.

If a ball upon leaving the mouth of a cannon (fig. 4) were never to meet with any resistance to its projectile force, it is evident it would travel onward to infinity: but on approaching a large mass of matter, the law of

Fig. 4.



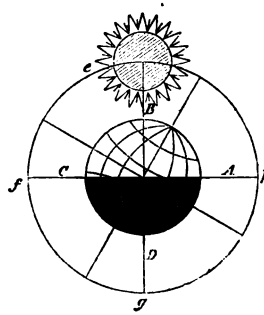
attraction would oppose a resistance to its further progress, and the two bodies conjoining would remain in a state of rest. But if the distance of the attracting mass from the line of projection were such as to prevent it entirely overcoming the projectile force of the cannon-ball, the result would be that its line of projection would be curved round the attracting mass—the two tendencies counteracting each other—one, the centripetal, detaining the ball near the mass; the other, the centrifugal, tending to its escape in a right line. A second mass of matter at A would add its attractive force to the ball, and the consequence of this would be a divergence of the ball towards A, causing its circular path to be converted into an elliptical one. In this exemplification we have the reasons and laws of the motions of the heavenly bodies in space.

36. The earth, obeying the attractive forces of the sun and systemic planets, travels round the former in

an elliptic orbit in 365 days; performing a complete revolution on her axis in twenty-four hours.

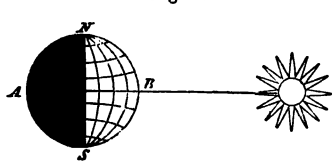
The axis of the earth is not upright or perpendicular to the plane of the ecliptic,* A C, but inclines or leans towards it 23½ degrees, making an angle with it of 66½ degrees. It will be seen by fig. 5 that only one hemisphere of the earth can be illuminated by the sun, while the other remains in darkness. It is said, therefore, in accordance with the false appearance that the sun rises in the east and sets in the west, and so causes our day and night. Fig. 5 shows the real motion, A B C D representing the diurnal motion of the earth: to an inhabitant at A the sun will be rising; when he reaches the vertical point B, it will be noon; at C, the sun to him is setting, to rise again to him when he returns to the point A.

Fig. 5.



This also explains the apparent motions of the whole sidereal bodies every twenty-four hours. If the axis of the earth N S (fig. 6) were perpendicular to the line A B, there would be equal day and night throughout the year

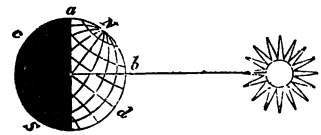
Fig. 6.



* The *ecliptic* is an imaginary circle the sun appears to describe in its apparent annual revolution among the stars—*e f g h* (fig. 5).

—the two poles excepted. If the earth were thus situated, the sun's rays would always fall vertically on the equator,* which would be heated to a high degree, while the regions round the poles would be desolated by perpetual winter. Instead of this, the axis of the earth being inclined $23\frac{1}{2}$ degrees, the length of the days and nights are unequal, depending upon the length of time the sun remains above the horizon,† and this position of the earth with regard to the sun also causes the varieties of temperature called the seasons,—*a b* (fig. 7) representing the circle of latitude in which London is situated, it is evident that about two-thirds of it is in the light, and only one-third in darkness; hence the sun will be two-thirds or sixteen hours above the horizon, and eight hours below it. The parallel above *a b* is entirely in the light, and from thence to the pole there is continual day for some time, and at the pole the sun shines for six months together. During that time, the south pole is involved in darkness. To those who live in equal latitudes, the one north, the other south, the length of the days to the one will be equal to the nights of the other.

Fig. 7.



* The *equator* is a line drawn round the earth, A B (fig. 6), and *c d* (fig. 7), equidistant from the poles, dividing the earth into two hemispheres, a northern and southern.

† The *horizon* is that circle of the earth which bounds the view of the spectator; consequently, the higher the spectator ascends from the surface, the greater will be the extent of the horizon. This is termed the sensible horizon. The *rational horizon* is supposed to encompass the globe exactly in the middle, and applies to the rising, setting, &c., of the sun, moon, and stars.

37. The earth in its present form and physical constitution may be described as an oblate spheroid, its surface unequally divided into land and water. Around and moving with it is a highly elastic invisible aerial ocean, the atmosphere, extending from the surface into space about forty-five miles.

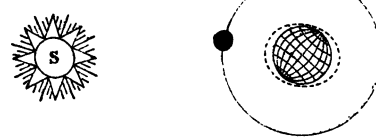
38. The water of the earth is a denser fluid than the air, filling the hollows and inequalities of the earth's surface. Were the surface of the earth perfectly smooth, the ocean would cover and surround it in like manner as the atmosphere, and by reason of its gravity, preserve a constant level. But the surface of the earth being unequal, broken into great chasms, and rising into heights above the level of the water in the latter instance, and sinking below it in the former, we have in consequence, oceans and seas, plains and mountains.

39. These waters, covering more than half the surface of the globe, are in continual motion, but this motion is regular and exact, and is called *the tides*, or the flux and reflux of the sea. These constant and exact motions are occasioned by the attraction of the sun and moon in antagonism to that of the earth, and by the centrifugal force of the waters in motion. The attractive force of the earth retains the waters, but the attractive power of the moon, which from its nearness is much greater than that of the sun, partly overcomes the retaining power of the earth and gathers them into a greater body as the diurnal motion of the earth brings them under its attractive influence, and of course this diurnal revolution must produce this effect twice in each day. The attractive force of the sun is calculated to that of the moon as three to ten.

When the sun and moon are in conjunction, that is, both on one side of the earth (fig. 8), their conjoint influences raise the waters immediately under them to a great height and constitute *high water;* at the poles,

on the contrary, the waters being drawn away, it is *low water*. But it will be seen that it is also high water on the opposite side of the earth; here the centrifugal force of the water in circular motion comes into action and causes the water to fly off to a certain height from the earth's surface. The sun and moon being in opposition, that is, on either side of the earth, the same height of tide is the result,—attraction and centrifugal force being in antagonism. These tidal conditions are called *spring tides*. When the moon is in her quarters, the influences of the sun and moon counteract each other; the influence of the one raising the water, while that of the other depresses them. The moon of herself would raise the waters ten parts under her, but the sun being then in a line with low water, his influence prevents the tides falling so low there, and consequently from rising so high under and opposite the moon; his power therefore being three parts leaves only seven parts for the high water under and opposite the moon. These are called *neap-tides*.

Fig. 8.



There are no tides in lakes and small seas, because, being confined, every part of the water is equally elevated when acted upon vertically by the moon.

40. There can be little doubt that the atmosphere is affected in like manner by the sun and moon, and being lighter and nearer, the aerial must rise higher than the oceanic tides.*

* See Sir Wm. Herschell's "Elements of Astronomy."

TERRESTRIAL MATTER.

41. The mountains, plains, and beds of the waters form the outermost surface, or, as it has been called, the *crust of the earth*. This crust is formed of matter chemically and mechanically combined, and the matters forming these combinations are recognised as *elementary substances*. These amount to fifty-five in number, forty-one of which belong to the class of metals, and are called metallic elements, while the others are termed non-metallic. They are as follow :—

NON-METALLIC.	METALLIC.		
Oxygen.	Arsenic.	Rhodium.	Strontian.
Hydrogen.	Tellurium.	Iridium.	Calcium.
Nitrogen.	Antimony.	Osmium.	Magnesium.
Chlorine.	Chromium.	Gold.	Zinc.
Iodine.	Vanadium.	Aluminum.	Cadmium.
Bromine.	Tungsten.	Zirconium.	Nickel.
Fluorine.	Molybdenum.	Thurium.	Cobalt.
Carbon.	Columbium.	Yttrium.	Copper.
Silicon.	Titanium.	Bismuth.	Iron.
Borax.	Uranium.	Tin.	Manganese.
Sulphur.	Ceranium.	Mercury.	Lithium.
Selenium.	Lantanum.	Silver.	Sodium.
Phosphorus.	Platinum.	Lead.	Potassium.
	Palladium.	Barium.	

It must be understood that these substances are *elements* to us only because we have not been able to divide or resolve them into simple ones. Future research may show a further division, and many proved to be compounds. This very probably will be found to be the case with all those substances not recognised as gases.

42. The chemical and mechanical combinations of these elementary substances are so materially and importantly influenced by the agencies of Heat, Light, and Electricity, that a description of these imponderable bodies, as they are termed, becomes necessary, in order

to comprehend the changes in form that elementary particles undergo.

43. HEAT, or *Caloric*, has been termed an imponderable body, because it neither adds to or takes away from the weight of any substance. The first source of heat is evidently the sun, and is supposed to be communicated by a subtile medium; the second source is combustion. Heat is also evolved when bodies of matter chemically alter the arrangement of their particles. Heat is given forth in electrical action; it is also produced when two hard bodies are rubbed together. Heat is said to radiate when it passes from a hot to a cold body through an appreciable interval; for example,—in standing before a fire our body is warmed by the heat radiating from the fire. Heat is said to be *conducted*,—this means, its passage from particle to particle through the substance of bodies. As it passes through bodies with different velocity, substances are therefore called *conducting* or *non-conducting* bodies; for example,—if one end of a rod of iron be left in the fire for some little time, the other could hardly be touched without danger of burning the hand; but a rod of wood might be consumed at one end without causing any sensation of heat at the other: the iron therefore is called a conductor of heat, the wood a non-conductor. A hot body cools by the heated particles on its surface giving off their heat, while the heat in the interior is conducted from particle to particle until it reaches the surface, when having radiated all its heat to the degree of its receiver—whether the atmosphere, water, &c.—it then remains in a state of equilibrium, to which state all heated bodies are constantly tending. Heat can be reflected by a second body to a third; a red-hot ball placed before a polished metallic mirror will have its heat reflected from the mirror to a body placed in its focus. Heat is emitted from the surface of a hot body equally in all directions, and in

right lines like radii from the centre to the surface of a sphere. Bodies receive heat with great difference; some, such as glass, permit the rays of heat to pass through their substance. The colours of bodies also modify the reception of heat. The effects of heat may be said to render it the antagonist power of attraction. When a body is heated it is enlarged in bulk by causing a repulsion of its particles; this necessarily renders it of less specific gravity.

44. *Specific gravity* is the difference between the weight of a given bulk of water, and the same bulk of any other substance. The bulk of water is taken as one, and the difference in weight of the same bulk of any other substance will be its specific gravity. Supposing a given bulk of matter to weigh 360 grains, and the same bulk of water to weigh 60, it is evident it requires six times the weight of the body to equalise the water in bulk; the weight 360 grains being divided by 60, the weight of the water, will give the quotient 6 as its specific gravity. Gases being lighter than water, an equal bulk would therefore be a fractional part of the weight of the water, and the difference, the specific gravity

45. An aperture which would just admit a rod of iron would be found too small if the iron were heated. This effect of heat causes the particles of bodies, first to assume a different relative position to each other, and then to cause them to fly off in different directions; so that a solid body may by the application of heat become fluid, and the fluid by increase of intensity of heat become dissipated in vapour; for example, a quantity of ice at 32° would become water at any heat above that, and remain so until it reached 212°; beyond that it would become vapour, and its particles be dissipated through the atmosphere. The decrease of heat, on the contrary, causes the particles of all bodies to approach

each other, and in the above example, the vapour upon cooling would be condensed to water, and the water consolidated to ice. It will be perceived therefore that, in determining the specific gravity of bodies, the relative bulks should be of equal temperature; consequently pure water of 60° Fahrenheit is taken as the standard.

46. All chemical processes in matter are influenced by heat; by its means bodies previously separate are made to combine, and elements of compound substances are disunited. A certain intensity of heat is destructive of most substances.

47. The expansion and contraction of bodies by heat is made the means of measuring the intensity of heat and cold; the instrument by which this is effected is called a thermometer.

A glass tube with a bulb at the lower end is fitted upon a frame, and the bulb filled with mercury. By applying heat of known degrees—as boiling water—the expansion of the mercury is marked upon the frame 212°; on cooling it to the freezing point of water, 32° is marked on the frame, and these two points being established, it remains to divide the intervals into degrees. These degrees were established by Fahrenheit, and is the instrument in general use in England, but on the continent other modifications of the instrument are in use.

48. When bodies capable of becoming incandescent are heated, combustion ensues, and in many instances flame is produced.

The flame of a lamp or candle is seen to consist of three portions,—a dark central part, consisting of combustible matter drawn up by the capillarity of the wick —a highly luminous cone or envelope, surrounding the dark portion—and on the outside of this may be traced a second cone having an exceeding high temperature.

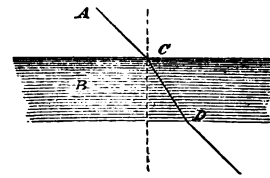
49. LIGHT is an emanation from the sun, or a body in combustion; it is also the result of electrical action. Phosphorus, decaying animal matter, and some vegetable substances have the power of emitting light. This power is also possessed by some insects, and marine animalculæ. Sir Isaac Newton imagined it to be shot from the sun in straight lines, in infinitely small particles; others (Huygens and Swedenborg) have considered that light is the result of a vibratory motion of a highly elastic medium of excessive tenuity, and filling all space. This undulating or wave hypothesis of light, is now generally considered to be the true one. Light, like heat, is reflected from solid bodies according to the nature of the surface. A ray of light is compound, that is, composed of many coloured rays. Some bodies reflect the ray of light entire as it falls upon them, these bodies therefore appear white; others absorb the entire ray, and black is the appearance produced; other bodies decompose or separate the component rays, reflecting some and absorbing others, the body then appears to be of the colour reflected.

50. The colours that compose a ray of white light are seven,—violet, indigo, blue, green, yellow, orange, and red. If a ray of light be caused to pass through a triangular prism of glass it will separate into a number of coloured rays, and if received upon a white surface they will be seen in the order mentioned above, but graduating imperceptibly into each other. A ray of light falling on a transparent medium, such as glass, water, diamond, ice, &c., is transmitted and illumines bodies on the farther side, but in passing through the medium, its direction from a straight line is altered by being bent during its passage to an angle, but resuming a parallel straight direction when emerging from the translucent body.

Suppose A a ray of light striking the surface of the

transparent body B, it will become bent in the direction C D, and on its emergence will travel in the direction E.

Fig. 9.



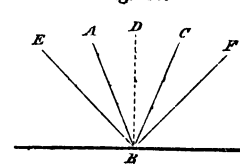
This law is called *Refraction.*

51. Again, if a ray of light be suffered to fall upon a plate of glass of 56° 45′, the portion of the ray which suffers reflection will be found to have acquired properties it did not before possess, for, on throwing it under the same angle upon a second glass plate, it will be observed there are two particular positions of the latter in which the ray ceases to be reflected. Light which has suffered this change is said to be *polarised.*

Light striking upon a plane surface is reflected at an angle equal to the perpendicular on either side.

A ray of light A falling at the point B, will be reflected B C, forming an equal angle with the perpendicular D. A ray falling at E B, will be reflected B F by the same law.

Fig. 10.



52. The media by which heat and light are manifested, appear to be, if not identical, to have the most intimate resemblance. "If light be due to ethereal vibrations, it is difficult not to assign a similar cause to radiant heat: they are distributed, absorbed, and transmitted." (Liebig's Elements of Chemistry.)

53. Electricity.—There are certain phenomena observed in relation to the chemical changes of the forms of matter; certain phenomena exhibited in the alternations of atmospheric conditions; certain phenomena

made apparent by the friction of different substances, so that two substances shall appear to attract and repel each other in consequence of being thrown into a certain state and condition. These phenomena are recognised as the result of a power which has been called *Electricity.*

What is the true nature or cause of these so-called electric phenomena we are ignorant, but it is presumed, and taken for granted, that a highly-attenuated and subtile form of matter pervades all space and all material forms; and that under ordinary circumstances it is in a state of equilibrium or quiescence, and this has been termed the *electric fluid.* When disturbed or thrown into action it is *electricity.*

Our ignorance of the true nature of this most important natural power, makes it all the more difficult to define and reduce its laws, or reconcile their apparent discrepancies.

From the very opposite effects produced, it has been likewise supposed that two distinct fluids exist, equally subtile, equally diffused, and each repulsive of its own particles, but attractive of those of its opposite kind; hence we have the terms *positive* and *negative* electricity. In the ordinary or quiescent state these fluids are supposed to be combined with, and exactly to neutralise each other; and electrical excitation is attributed to their separation, or to the decomposition of the neutral fluid. The first hypothesis of a single fluid has the recommendation of simplicity, and is mostly sufficient to account for the greater number of electrical phenomena; but the second appears to reconcile some apparent difficulties. The perfect comprehension, however, of the terms *positive* and *negative*, as applied to electricity, will render it of little moment which of the above hypotheses is the true one. The manifestations of the existence of this power are as follow: firstly, it is seen in

its most intense activity in lightning; in a feeble and more diffused form in the aurora borealis, or northern lights; and when glass, amber, or sealing-wax be rubbed with a dry cloth, they acquire the power of attracting light bodies, as feathers, dust, or bits of paper: this, perhaps, is the feeblest manifestation of electricity. If a light downy feather be suspended by a thread of white silk, and a dry glass tube, excited by rubbing, be presented to it, the feather will be strongly attracted to the tube, adhere to its surface for a few seconds, and then fall off. If the tube be again rubbed and presented to the feather, the latter will now be strongly repelled. Sealing-wax will present the same circumstances.

The glass tube in this instance is excited by positive electricity, and attracts the feather; the feather, becoming electrically excited by the positive tube, is repelled by the tube when presented a second time. But if a stick of sealing-wax, excited by rubbing, be presented to the feather in its *positively* excited state, the sealing-wax, being *negative*, will attract it with a force much greater than the first attraction by the glass tube. This experiment establishes the following electric principles: firstly, bodies in a positive state of electricity will attract others in a state of equilibrium; secondly, bodies in a positive state repel others in a similar electric condition, but are attracted to those in an opposite or negative state.

54. MAGNETISM.—A particular species of iron ore has long been known for its property of attracting small pieces of iron, and causing them to adhere to its surface; it is called *load-stone*, or magnetic iron ore. If a bar of steel be rubbed in a particular manner with one of these natural load-stones, it will acquire and manifest the same magnetic properties as the ore. This is called *Magnetism*, and until late years was believed to be a distinct property residing in the above substances. It is now,

however, considered that what is termed *magnetism*, is only a modification of electricity. "If amber," says Pliny, "becomes inspired by friction and warmth, it attracts bark and dried leaves exactly like the magnetic iron-stone." This ancient opinion is thus endorsed by the modern Pliny,—Humboldt: "Magnetism is one of the numerous forms in which electricity manifests itself." Electricity and magnetism may therefore be considered together, the one a modification of the other.

If a piece of load-stone be carefully examined, it will be found that its attractive force is greatest at particular points of its surface, whilst elsewhere it is much diminished, if not absent. These attractive points are termed poles. When a natural magnet, or magnetised bar of steel, is suspended at its centre in any convenient manner, so that it shall freely move in a horizontal plane, it is always found to assume a particular direction with regard to the earth; one end pointing nearly north, and the other nearly south. If the bar be removed from this position it will tend to re-assume it, and after a few oscillations, settle at rest as before.

A magnet thus suspended forms the instrument termed the mariner's compass.

If the north pole of a second magnet be presented to a south pole, mutual attraction ensues. If a north pole be presented to a north pole, or a south pole be presented to a south pole, mutual repulsion ensues—thus opposite poles attract, and similar ones repel each other. One kind of polarity cannot be exhibited without the other. When a natural magnet is used to induce or magnetise a bar of iron (then termed an artificial magnet), an opposite state of polarity is always induced—that is, whichever end of the magnet is used to magnetise the iron, the end of the iron bar so magnetised will be its opposite pole. The direction spontaneously assumed by a suspended magnetic needle, indicates that

the earth itself has the properties of an enormous magnet, whose south pole is in the northern hemisphere.

If the magnetic needle be supported on a horizontal axis, it will present the following phenomena:—at the equator the needle will remain nearly or quite horizontal; as it is made to approach the poles of the earth, it will alter its position vertically, until, at the terrestrial pole, it will become absolutely vertical. This is termed the *dip of the needle.*

On comparing these phenomena with those of electricity, a perfect parallelism, if not identity, is perceived.

55. When the equilibrium or quiescent state of electricity is disturbed, an immediate tendency to its restoration takes place. This restoration is effected by an explosion more or less violent. In an atmospheric electric storm, the unequal accumulation of electric matter is restored to its equilibrium by explosive violence, accompanied with flashes of light and thunder.

In order to produce artificial disturbance of electric equilibrium, a machine has been invented which accomplishes this object by rubbing a glass cylinder or plate with a cushion of silk smeared with an amalgam of mercury, zinc, and tin. The accumulation of electric fluid thus produced by the "electrical machine" is carried off by what is termed a conductor, and is either conveyed into a receptacle arranged for the purpose, or discharged by restoring the equilibrium, which is effected, as in the case of the atmospheric electric storm, by an explosion producing a spark of light and a slight noise. Like the polarity of magnetism, one kind of electricity can no more be developed than one kind of magnetism; the rubber and the body rubbed always assuming opposite states—the rubber accumulating the *negative*, the body rubbed, the *positive* electricity.

56. A conductor of electricity is one of a class of bodies which will not allow of an accumulation of electric matter upon their surface; that is, if their surfaces are electrically excited by friction, the electric matter is carried off immediately to the earth and all surrounding bodies; for this reason they do not appear to become electrical, but this is only an appearance.

57. A non-conductor, on the contrary, permits the electric fluid to accumulate upon its surface, to be carried off by a conducting body. The best conductors are the metals; of these silver and copper are the best; next follow gold, zinc, platinum, iron, lead, antimony, and bismuth. Then follow charcoal, acid-liquids, solutions of salts, animal substances, water, and gases which have been rarified by heat, or charged with a large quantity of moisture.

If a copper rod be elevated above a building and connected below with the earth or water, it conducts the lightning as it is termed, or electric fluid, harmless to the earth, and thus protects the building from damage.

58. The principal non-conductors are sulphur, resinous substances, glass, air, wood, paper, hair, silk, feathers and wool. Conductors therefore are non-electrics, and non-conductors are electrics.

59. In order to accumulate a quantity of electric fluid, a glass jar is prepared by coating it inside and out with tin-foil to within a few inches of the top. A brass wire surmounted by a knob is made to communicate with the interior coating, and the jar is then ready to receive its charge of electricity. This is called the *Leyden-jar*. To *charge* the jar, the knob is held near the conductor of the electrical machine. A succession of sparks will pass into it, at first rapidly, then slowly, and at length ceasing altogether. The jar is then charged. To *discharge* it, a metallic wire is made to connect the

outer and inner coatings of the jar, when a bright spark attended by a snapping noise will pass from the knob; the jar is then said to be discharged,—in other words, the *electric equilibrium* is restored, precisely as in the case of an electric thunderstorm. A number of these jars may be connected, and a large quantity of electric fluid accumulated: such an arrangement is called an *electrical battery.*

60. Electricity may be produced during the chemical decomposition of substances in contact, and to effect this a machine called a galvanic battery (from Galvani, who first discovered the fact) is so constructed that two plates of metals, copper and zinc in contact, are immersed to a certain depth in a vessel containing dilute sulphuric acid: a current of positive electricity passes uninterruptedly from the zinc through the liquid to the copper. If the plates be multiplied, a powerful spark may be produced.

61. To measure the kind and intensity of electricity when produced, various instruments have been invented called *Electrometers.*

62. Changes of temperature elicit magnetic and electric currents, and that there is a constant current of the electro-magnetic fluid is evident from the phenomena produced by the atmospheric electric storms, and the aurora or magnetic storm. The magnetic needle is greatly influenced by these occurrences.

LAWS OF ATTRACTION AND AFFINITY.

63. The *forces* of nature, as yet mentioned, have been the varieties of attraction, gravity,—and electric attraction, and their antagonistic forces—heat and electricity.

There is another natural and universal attractive power, termed *chemical attraction.* This peculiar attractive force or law is the one by which all elementary

substances arrange themselves into bodily forms. This self-arrangement cannot take place without these substances being in a state of fluidity, either by solution or igneous fusion; or at least one of the substances. For example, potash and tartaric acid, if mixed in dry powder, would never manifest any alteration; but if potash be dissolved in pure water, and tartaric acid be added, immediate alteration takes place; their particles re-arrange themselves into a new and different substance, which is neither potash nor tartaric acid; the potash leaves its carbonic acid, and uniting itself with the tartaric acid, forms tartrate of potash (cream of tartar), and this new substance is thrown down in the vessel. We see in this example, that potash when it has the opportunity prefers to unite itself with tartaric acid, than to continue its alliance with carbonic acid, which it immediately sets free: this preference chemists term *affinity*. This invariable law is of the highest importance in chemistry, and to it are subservient the almost infinite combinations of material substances, though modified and sometimes suspended by heat, light, and electricity.

64. Another modification of the law of attractive force, also, impels a large class of inorganic substances to arrange their atoms into certain and invariable geometric forms. This is termed *homogeneous attraction*, or aggregation of atoms; and the bodies resulting from this formative law are called *crystals*, and the process *crystallization*. Most of these substances have their determinate forms peculiar to their nature and composition, but many very different in their composition have an identity in form of crystal.

Crystallization takes place when substances pass from a liquid into a solid form: a familiar illustration of this is seen in water, which, when freezing, assumes symmetrical forms, as may be seen on a window in frosty weather. Sugar and common salt are further examples.

If dissolved in water and the solution allowed to evaporate, they again assume the solid form, by their particles resuming their crystalline arrangement. Crystallizable substances assume all the various modifications of geometric forms, as cubes, prisms, rhomboids, &c.

CHEMISTRY OF THE ELEMENTARY SUBSTANCES.

65. Having thus briefly noticed the properties of the imponderable agents, together with the laws governing the attractive forces of matter, the description of the elementary substances with their combinations naturally follows.

Oxygen in its elementary state is a gas, but is always found in nature mechanically and chemically combined with other substances. In a combined form it constitutes at least $\frac{3}{4}$ths of the known terraqueous globe. Thus, water which covers $\frac{3}{4}$ths of the earth, contains $\frac{8}{9}$ths of its weight of oxygen, and the solid crust of the globe probably consists of at least $\frac{1}{3}$rd part by weight of this principle. Silicon, carbonate of lime, and alumina, the three most abundant constituents of the earth's strata, contain nearly half their weight of oxygen.

In the organized kingdom oxygen is an essential constituent of all living bodies: it is the main supporter of combustion. When oxygen unites with other substances, it is termed oxidizement, or oxidation. All the elementary substances are susceptible of oxidizement. When this takes place, acids, alkalis, earths and oxides are the result, and they are either effected slowly and without the evolution of heat and light, or rapidly with combustion and flame; or with intermediate rapidity with great increase of temperature, though without flame. Its specific gravity is greater than that of air: if air be estimated at 1000, oxygen will be 1102·6. It is a non-conductor of electricity.

66. *Hydrogen* is next to oxygen in importance as a constituent of the globe: it constitutes 11 per cent, by weight of water. It is a colourless tasteless gas, very inflammable, and is the lightest substance in nature, being 14·4 times lighter than air. In the organized kingdom it is an essential constituent of both animals and vegetables. With oxygen it forms water. This is not a mechanical mixture, as in the instance of atmospheric air, but a chemical combination. If a mechanical mixture of the two gases be inflamed by the electric spark, the gases totally disappear, and water equal in weight is formed.

67. Water exists in the atmosphere, and forms on the surface of the earth, seas, lakes, and rivers. In the atmosphere it is found as vapours, and in a vesicular form it constitutes the clouds. It forms about $\frac{3}{4}$ths of the surface of the earth. Water enters into the composition of minerals, and in the organized kingdom is an essential constituent of vegetables and animals. In the liquid state it is volatile, tasteless, and odourless; below 32° it congeals into a solid body called Ice. If water be submitted to the influence of the galvanic battery, it is decomposed into its constituent gases. Water absolutely pure does not exist in nature, being always charged in various degrees with air, or with animal, vegetable, or mineral substances. Sea-water contains $3\frac{1}{2}$ per cent. of saline matters. The alternate expansion of water into steam, and the condensation of the latter into liquid, is the moving power of the steam-engine.

68. *Nitrogen* or *azote*, in its elementary state, is a colourless tasteless gas. It is one of the very few elementary bodies found in an uncombined state. The great bulk of this gas is confined to the atmosphere, of which it constitutes $\frac{4}{5}$ths, and enters largely into the composition of organic substances.

69. Atmospheric air is a mechanical mixture of nitrogen and oxygen gases, in the following proportions:—

	BY MEASURE.	BY WEIGHT.
Oxygen	21	23
Nitrogen	79	77
	100	100

It is 815 times lighter than water. At the temperature of 60° its specific gravity is estimated at 1000, and assumed as the standard of comparison for other gaseous bodies. It is elastic and compressible. Its pressure on the earth at the level of the sea is equal to a weight of fifteen pounds on every square inch of surface, and is capable of supporting a column of mercury of thirty inches. The pressure of the atmosphere diminishes with its elevation, the upper strata being more expanded than the lower upon which they press; a column of mercury, therefore, that stood at thirty inches at the level of the sea, would fall to fifteen inches at a height of 11,566 feet, and the progression of the rise and fall of the mercury being known, the barometer becomes an instrument by which the height of mountains can be measured. The temperature of the atmosphere varies with its elevation: it is greatest at the surface of the earth, and diminishes 1° for every 352 feet of elevation in the lower strata; at higher distances the progressive fall of the temperature is less rapid. The reason for this is, principally, the atmosphere derives its heat, not from the rays of the sun, but from the earth; its temperature therefore is lower the further it is removed from this source of heat. In the warmest climates there is a point above the surface at which the thermometer never rises above 32°, the freezing-point of water; con-

sequently, if a mountain-top reach that point, it is covered with perpetual snow.

70. Nitrogen combines with oxygen in five proportions, forming as many compounds. One of these, the *nitrous oxide*, is called the *laughing-gas* in consequence of its intoxicating properties. A second is nitric acid or aqua-fortis; this acid forms with metals a class of salts called Nitrates.

71. *Chlorine* in its elementary state is a gas, but in this state it never occurs naturally. It is found in both kingdoms of nature. In the inorganic it exists principally in combination with sodium, either dissolved in the ocean, or forming deposits of rock salt. It occurs, also, in combination with magnesium, calcium, lead, &c. In the organized kingdom it is found in vegetables and animals. Under pressure, chlorine gas can be made to assume the liquid form,—resuming the gaseous on the pressure being removed. Chlorine has the properties of discharging all colours, and is, therefore, most valuable as a bleaching power. It is also a disinfecting agent.

72. *Carbon* is a substance which occurs under a variety of forms. In its crystallized and pure state it constitutes the diamond, the hardest and most brilliant body in nature; it is also in a state of purity in Plumbago or Graphite. It constitutes a large proportion of all organic structures; and when they are exposed to destructive distillation in closed vessels, it is obtained in the form of charcoal. Combined with oxygen it forms carbonic acid gas; and in this form, is found mixed with the atmosphere. With lime it constitutes chalk and limestone, two of the most abundant minerals in nature. This acid is discharged from volcanoes in great abundance, and from fissures in rocks, as at the Grotto del Cane, near Naples; the Valley of Poison in Java, and elsewhere. Carbonic acid does not support combustion; it extinguishes the flame of all burning bodies.

The pungent taste and effervescence of aërated waters and wines are owing to the presence of carbonic acid gas. It is a poison to animal life when inspired. It is the fatal *choke-damp* of mines. Its specific gravity is 1·524.

73. *Iodine* is met with in nature in combination with potassium, sodium,—in seaweed, sponges, and marine animals. It is obtained in octohedral crystals of a greyish-black colour, with an imperfect metallic lustre. It possesses an extensive range of affinity, combining with oxygen, hydrogen, and with most of the metals.

74. *Bromine* is obtained from the same sources as iodine, and its chemical relations are very similar.

75. *Fluorine* has never been obtained in its elementary state, consequently its existence has been rather inferred than proved. It is found combined with the mineral called Fluor-spar. In combination with hydrogen it forms a most destructive compound, called *hydrofluoric acid;* it acts energetically on glass, and is used by glass engravers for that purpose.

76. *Boron* is found in vapour condensed from volcanic springs. It combines with oxygen to form *boracic acid.* This is the borax of commerce.

77. *Sulphur* exists naturally in an elementary state. It is exhaled from volcanoes in a pure state, or in combination with hydrogen, forming a very deleterious gaseous compound called *sulphuretted hydrogen.* It is found in vegetal and animal products. It is a brittle crystallizable solid, of a greenish-yellow colour, and almost imperceptible taste. It is fusible, volatilizable, and combustible. In atmospheric air it burns with a pale blue flame, and emits a peculiar suffocating fume called *sulphurous acid.* It crystallizes in two distinct forms, an octohedron and a lengthened prism. Its chemical relations to other substances are very numerous; in this respect bearing great resemblance to oxygen. With the latter it forms six compound acids, the principal being

sulphuric acid. This acid combines with metallic bases, and are called sulphates.

78. *Silicon* is the elementary basis of silex or flint, one of the most abundant minerals in nature. Silicon by combustion, combining with oxygen, is converted into flint-earth; it is the chief ingredient of sand, sandstone, chalcedony, rock crystal; and under the name of quartz forms rocky masses.

Glass is a silicate; the varieties depending on the alkali or oxide used in its manufacture. Thus, with three parts of carbonate of potash and one of silica, a glass is formed which is soluble and deliquescent: if an excess of silica be employed, the glass is insoluble. Common bottle glass consists of impure silica and the most common kind of pearl-ash. Window glass is made from a purer silica and a purer alkali; plate glass from sand and alkali in their purest state. Flint glass contains a portion of red-lead. Silica constitutes about 45 per cent. of the mineral crust of the globe.

79. *Phosphorus* is a pale amber-coloured substance resembling wax in appearance. It does not exist in an elementary state, but is obtained from various products. It is exceedingly inflammable: gentle pressure between the fingers, friction, or percussion kindles it readily. Upon mere exposure to the air it is gradually consumed, emits a white vapour, and appears luminous in the dark. It is found in the mineral kingdom combined with lime, lead, iron, copper, manganese, uranium, and yttria. In the organized kingdom it is found in various vegetables; in animals, in combination with lime, it forms the principal constituent of bone.

80. *Selenium* is a most rare substance in nature; it somewhat resembles sulphur in its chemical relations. It is brittle, and of a reddish-brown colour. It forms three oxides with oxygen.

81. *Tellurium* is of very rare occurrence. It is found in association with silver, lead, and bismuth. It is of a bright grey colour, brittle, fusible, and volatile. It forms two compounds with oxygen. The three or four last elements form an intermediate class between metallic and non-metallic elements.

82. The metallic bodies very rarely occur in an elementary state. They are usually found associated with other bodies and are termed *ores*. The metal is separated from the ore by chemical processes. Ores are found in fissures in rocks, termed veins, and often in beds of earth.

Combinations of the metals with each other are termed alloys; but when mercury is one of the constituents it is called an amalgam.

All the metals are conductors of heat and electricity; they are all positive electrics. They are lustrous and opaque, and generally good reflectors of light. Metals combine in various proportions with the gaseous elements and form salts. The metallic elements may be classed into those that form the bases of the alkalis and earths, and those that form the bases of the acids. Of the first class, potassium, sodium, and lithium form the bases of alkalis;—barium, strontium, calcium, magnesium, aluminium, glucium, yttrium, thurium, and zirconium of the alkaline and pure earths. The remaining metals may be said to form the bases, more or less powerful, of the oxides and acids.

83. *Potassium*, the base of the alkali *potash*, is a brilliant white metal with a high degree of lustre. At the common temperature of the air it is soft, but at 32° it is brittle and crystalline. It is lighter than water; exposed to the air, potassium oxidizes instantly, and if thrown upon water, takes fire spontaneously and burns with a purple flame, yielding an alkaline solution. Potassium combines in two proportions with oxygen. With nitric acid it forms nitre; with carbonic acid,

pearl-ash and salt of tartar. Cream of tartar is a tartrate of potash. In vegetables, potash is found combined with phosphoric, sulphuric, nitric, and carbonic acids.

84. *Sodium* is a silver-white metal greatly resembling potassium in every respect. It is soft at common temperatures, and oxidizes readily in the air: it floats on the surface of water and rapidly oxidizes, but without taking fire like potassium. Sodium combines with oxygen, sulphuric and carbonic acids. Combined with chlorine it forms chloride of sodium, or common salt. This very important substance is found in many parts of the world in solid beds of immense thickness. Large quantities exist in mineral springs; and the waters of the ocean contain 2 per cent. of this salt. In the organized kingdom it is found in plants which grow by the sea-side, and in the fluids of animals.

It has long been surmised, that ammonia is a salt having for its basis a metallic element similar to potassium and sodium. Although the metal ammonia has not yet been isolated in a pure state, an amalgam of ammonium and mercury has been obtained.

85. *Lithium* is a white metal resembling sodium, and of highly oxidizable quality. Lithia is an oxide of lithium, and occurs but in small quantities in certain minerals.

86. *Barium* is a grey-coloured metal, with a lustre inferior to cast iron. It attracts oxygen with avidity from the air, and the oxidized metal is baryta. It combines with chlorine, nitre, sulphuric and carbonic acids, and sulphur.

87. *Strontium* is a heavy, white metal; decomposes water, and oxidizes quickly in the air; in both cases Strontia is formed, which so closely resembles baryta that they were once supposed to be identical substances. It combines with chlorine, and with nitric acid it forms the salt that produces the red fire of the pyrotechnist.

88. *Calcium* is a silver-white and extremely oxidizable metal. Lime, the earth formed by oxidation, is a brittle, white, solid earth. It has a powerful affinity for water, and the combination is attended with great increase of temperature, and the formation of a white bulky hydrate. This combination is termed *slaking lime*, and the hydrate itself is called *slaked lime*. With chlorine calcium forms a chloride of lime, existing in sea-water and many saline springs. It is a powerful disinfectant. In the mineral kingdom lime is found in the forms of carbonate, sulphate, phosphate, silicate, arseniate, tungstate, borate, and titanate. In vegetables lime is a constant ingredient combined with carbonic, sulphuric, phosphoric, and nitric acids. In animals lime is found principally as a carbonate and phosphate; the latter is the basis earth of bone. The fluoride of calcium is the well-known fluor or Derbyshire spar. Carbonate of lime forms a considerable portion of the known crust of the earth. In its crystallizable form it constitutes marble; and in the form of chalk, constitutes massive rocks. It is an abundant constituent of animals, especially of the lower classes.

89. *Magnesium* is a white malleable metal, fusible at a red heat. Heated in the air it burns and produces magnesia, which is its only oxide. Sulphuric and hydrochloric acids dissolve it readily, evolving hydrogen. Sulphate of magnesia, or Epsom salt, occurs in sea-water; it crystallizes in rhomboid prisms. Magnesia also combines with phosphoric acid and silica. The magnesia of commerce, usually called *carbonate of magnesia*, is obtained by adding carbonate of soda or potash to a solution of sulphate of magnesia; a precipitate is formed, which is a combination of the hydrate and carbonates of magnesia.

90. *Aluminium*, when produced in the elementary metallic state, is in small scales or spangles with a

metallic lustre. The earth alumina, the only known oxide of this metal, is a substance very abundant in nature. The purest native alumina is found in the Oriental gems—the sapphire and ruby; they consist of nothing but this earth, with a small portion of colouring matter. Alumina is widely diffused; it is a constituent of every soil, and of almost every rock. Combined with silica it forms the plastic clays, from which the various porcelains, potteries, and bricks are manufactured. The familiar alum is a double sulphate of alumina and potash; it crystallizes in the form of octohedrons. It is extensively used in the arts.

91. *Glucinium* has been found only in three rare minerals—the euclase, the beryl, and emerald. It is a grey substance, having a slight metallic lustre.

92. *Yttrium* is the basis of a very rare earth, yttria. It combines with sulphur, selenium, and phosphorus.

93. *Zirconium* is a black substance which acquires a feeble lustre. Zirconia is a rare earth, much resembling alumina in its characteristics.

94. *Thorium*, the metal of the earth thorina, has precisely the same characteristics as zirconium, and remarkable only for its great specific gravity.

95. *Manganese* is a hard brittle metal, exhaling a peculiar odour when handled or breathed upon. It combines with oxygen, chlorine, sulphuric, and carbonic acids. It is found in the ashes of plants, in the bones of animals, and many minerals. The oxides are extensively used in the manufacture of glass.

96. *Zinc* is a bluish white metal which slowly tarnishes in the air. It is procured from the native carbonate called *calamine*, or from the native sulphuret called *zinc-blende*. It combines with oxygen, chlorine, and carbonic acids. With sulphuric acid it forms the sulphate of zinc, or white vitriol. In alloy with copper it forms *brass*, and with copper and nickel, the *tutenag* of

the Chinese. Of late years zinc has become a very important metal in manufactures.

97. *Iron* is perhaps the most important to man of all the metallic elements; its usefulness is paramount over the others, and the onward progress of the human intellect is more dependent upon this, than any of the more brilliant and costlier elements. Iron in its pure metallic state is of exceedingly rare occurrence. It has a whitish-grey colour and perfect lustre. It is found in the greatest abundance in nature, combined with oxygen, silica, sulphur, and carbonic acid; and it may be said there are few mineral substances in which iron may not be detected. In the organic kingdom it is found in vegetables, and in animals, in the blood. The metallic masses, called meteoric stones, are mostly composed of this metal. Iron combined with the cyanuret of potassium forms the pigment called *prussian blue*, and with sulphuric acid the *green vitriol* of commerce. Steel is a carburet of iron.

98. *Cadmium* resembles tin in colour, but is somewhat harder; it is very malleable, and nearly as volatile as mercury. It accompanies the ores of zinc, and being more volatile rises first in vapour, when calamine is subjected to distillation. It combines with oxygen, chlorine, sulphur, and sulphuric acid.

99. *Cobalt* is met with in the earth, chiefly in combination with arsenic; it is found also in meteoric stones. It is, in its pure state, of a reddish-grey colour, brittle, and weak lustre. Like nickel it may be rendered magnetic. The chief use of cobalt is in the state of an oxide, as a colouring matter for glass, porcelain, and earthenware. This is the *smalt* of commerce.

100. *Nickel* is a metal of silvery-white colour, and is both ductile and malleable. It is found in some abundance in metalliferous veins, and also in association with iron and cobalt in meteoric stones. It combines with

oxygen, chlorine, sulphur, and carbonic acid. Nickel may be rendered magnetic. A mixture of nickel, copper, and zinc, fused together constitute the white alloy called *German silver*.

101. *Arsenic* is of a steel grey colour, crystalline in texture, and brittle, with a metallic lustre. It occurs only in the mineral kingdom. It unites with other metals in the same manner as sulphur and phosphorus. With oxygen it forms two acids.

102. *Bismuth* is a white metal with a reddish shade, and highly crystallizable. It is brittle when cold, but malleable when warm. It combines with nitric acid and oxygen. The alloys of bismuth are remarkable for their fusibility at a low temperature. The sub-nitrate of bismuth is used to form the *pearl powder* of perfumers. It is injurious to the skin.

103. *Copper* is a yellowish-red metal, malleable and ductile; an excellent conductor of heat and electricity. It is hard, elastic, and sonorous. It is mostly found in nature as a sulphuret of copper and iron. In perfectly dry air it is scarcely affected, but in a damp atmosphere the surface becomes decomposed and covered with a green crust, which is a carbonate of copper. Verdigris, or acetate of copper, is the result of the action of pyroligneous acid upon the metal. It combines with oxygen in two proportions; the combination of one of the oxides with sulphuric acid produces the "blue vitriol" of commerce. Copper combines with nitric acid forming the nitrate, and with carbonic acid forming the carbonate. The alloys of copper are of great importance. With 30 per cent. of zinc it forms *brass;* with 6 per cent. of zinc and 2 of tin it forms *bronze*. Gun-metal consists of 90 parts of copper and 10 tin; bell-metal of 100 parts copper and 25 of tin.

104. *Chromium* is a greenish-white metal, exceedingly difficult of fusion. It forms two compounds with

oxygen, and combines with chlorine and sulphuric acid. The emerald owes its colours to the presence of the oxide of chromium. Chromate of lead is used as a pigment.

105. *Tin*, in its pure state, has a white colour, approaching to that of silica; it is soft and malleable. It is nowhere found in its metallic state, but occurs usually in combination with oxygen. The principal locality in which it is found is Cornwall. It combines with oxygen, chlorine, and sulphur. Tin, in consequence of its non-oxidation by the action of water, is most useful in the manufacture of vessels for culinary purposes. *Mosaic gold* is a bi-sulphuret of tin. Pewter is an alloy of tin, antimony, and bismuth. Tin and lead form the plumber's solder.

106. *Lead* is a soft bluish metal possessing very little elasticity; it has a considerable degree of lustre, but soon tarnishes on exposure to air. It is both malleable and ductile. With oxygen it forms a yellow oxide called *litharge;* in another proportion, red-lead; and in a third, the brown oxide. With carbonic acid it forms *ceruse* or *white lead.* Sugar of lead is an acetate. With nitric acid a nitrate, and with chlorine a chloride, of lead are formed. Two parts of tin and one of lead are plumber's solder.

107. *Antimony* is a white brittle metal of considerable lustre. It is found chiefly in the state of sulphuret. It combines with three proportions of oxygen, and with chlorine forms a chloride. Antimony forms a very important alloy with lead, of which type-metal is manufactured.

108. *Mercury*, or Quicksilver, is a very remarkable metallic substance, by reason of its peculiar physical properties. It has a silver white colour with a high degree of lustre, and is distinguished from all other metals by being fluid at all common temperatures: at

40° below zero it solidifies and becomes malleable. It is found in nature occasionally in globules, but its native ore is generally a combination with sulphur,—the sulphuret or *cinnabar* of commerce. It combines with oxygen in two proportions, forming a black and a red oxide. With chlorine it forms two combinations—*calomel* and *corrosive sublimate*. With nitric acid it forms a nitrate. Vermilion is the sulphuret or cinnabar. Alloys of mercury with other metals are termed amalgams. An amalgam of tin and mercury is used to silver mirrors.

109. *Silver* is found in the mineral kingdom in various states, sometimes nearly pure, or alloyed with other metals; but the most abundant of its ores is the sulphuret. It has the clearest white colour of all the metals, and is susceptible of a lustre surpassed only by polished steel. In malleability and ductility it is inferior only to gold; a single grain may be drawn out into 400 feet. It is very soft when pure. Silver combines with oxygen in three proportions; also with chlorine, iodine, sulphur, and phosphorus. Dissolved in nitric acid it crystallizes and forms a colourless salt, the nitrate of silver, or *lunar caustic*. This salt upon exposure to light blackens and stains paper, skin, and any organic substance. This property enables it to be employed for marking linen, and forms *indelible ink*. Paper washed on one side with a solution of nitrate of silver and left to dry in a dark room, and then placed in a camera-obscura, may be made to receive the impressed likeness of a living person. This art has been termed *photography*. The chloride of silver is also sensitive to the impression of light. Fulminating silver is formed from a compound of oxide of silver and ammonia.

110. *Gold* is a soft metal, distinguished from all others by its beautiful yellow colour. It is always met

with in the metallic state associated with quartz, oxide of iron, and other substances in regular mineral veins. It combines with chlorine; and with oxygen forms two oxides. It is capable of receiving a high lustre by polishing, but in this respect is inferior to steel or silver. In ductility and malleability it exceeds all other metals; a grain of gold may be extended so as to cover fifty square inches of surface. Wood and other substances are covered by this thin leafing of gold, and made to adhere by means of size or varnish. A new method of gilding, simple and elegant, is superseding some of the others,—this is the *electrolysis*, or electrotyping.

111. *Platinum*, in colour a little whiter than iron, is the heaviest known metal, and is found in the metallic state associated with various metals; it also occurs in rounded or flattened grains. It is exceedingly malleable and ductile, but very infusible, melting only before the oxy-hydrogen blowpipe; for this reason it is used in the construction of some crucibles. It forms two compounds with oxygen and chlorine. It possesses the remarkable property of causing the union of oxygen and hydrogen gases; if a stream of hydrogen gas be directed upon a piece of spongy platinum, it immediately becomes red-hot and inflames the hydrogen.

112. *Palladium*, *Rhodium*, *Iridium*, and *Osmium*, form a group of metals found in the ores of platinum. They are procured in very small quantities, and appear to be very closely allied to platinum in their characteristics. Their properties however are but imperfectly known.

113. *Vanadium*, *Molybdenum*, *Tungsten*, *Columbium*, *Titanium*, and *Uranium*, are metals of very rare occurrence, and their properties but imperfectly known. They have not been applied to any useful purpose, with the exception of uranium, *pitch-blade*, which has been used in the arts as a pigment for staining glass.

114. *Cerium* and *Lantanum* are rare metals found associated in the Swedish mineral *Cerite*. Their discovery as distinct metals is recent, and their properties can hardly be said to have been ascertained.

115. Most of the metals are remarkable for their great specific gravity, and were formerly supposed to be the heaviest bodies in nature, but the discovery of potassium and sodium, which are so light as to float on water, has shown that this is erroneous. The following table shows the specific gravity of the various metals at 60°, compared to water as unity:—

Platinum	20·98	Nickel	7·788
Gold	19·257	Iron	7·97
Tungsten	17·6	Molybdenum	7·40
Mercury	13·568	Tin	7·29
Palladium	11·5	Zinc	7·
Lead	11·352	Manganese	6·85
Silver	10·474	Antimony	6·70
Bismuth	9·822	Tellurium	6·11
Uranium	9·	Titanium	5·30
Copper	8·895	Sodium	·972
Cadmium	8·640	Potassium	·865
Cobalt	8·538		

116. The tenacity of metals has been measured, by ascertaining the greatest weight which a wire of a certain thickness can support without breaking.

The following table gives the result of the amount of tenacity of the respective metals:—

Iron wire	supports	349·25 pounds
Copper	do.	302·278
Silver	do.	187·137
Gold	do.	150·753
Zinc	do.	109·54
Tin	do.	34·63
Lead	do.	27·621*

* For further details respecting the chemical relations of matter, the reader is referred to the works of Professors Brande, Graham, and Turner.

PRIMARY FORMATION OF THE TERRESTRIAL FORMS OF MATTER.

117. The whole of the matter forming the earth must have been, in its earliest stage of existence, in a state of fluidity at a very high temperature. "The figure of the earth is its history: an elliptical spheroid of rotation indicates a once soft or semi-fluid mass." (Humboldt's Cosmos). As the earth is one of a series of bodies of apparently similar character, it must be inferred that the original condition of all was alike. In this view it has been supposed (Vestiges of the Natural History of Creation) that our solar system was a nebulous mass of matter, with a very high degree of temperature. An outer ring of this mass being thrown off, it necessarily assumed the globular form, and became a revolving planet; this operation being repeated from time to time, a series of revolving planets would be formed around the nebular nucleus, increasing in density as they were thrown off; the same mode would explain the formation of the secondary planets or satellites. The evidences adduced in proof of this hypothesis are as follow:— Firstly, All the planets, with their satellites, move nearly in one plane corresponding with the centre of the sun's body. Secondly. The motions of the sun on its axis—the primaries round the sun, and the satellites round their primaries (with one exception), and the motions of all their axes are in one direction, from west to east. Thirdly. The densities of the planets are in direct relation to their distances from the sun, Saturn being of the density of cork, Mercury of lead. Fourthly. It has been calculated what ought to have been the rotation of the solar mass at the successive times when its surface extended to the various planetary orbits, and it is found that that rotation corresponds in every case with the actual revolution of the planets—and that the

rotation of the primary planets in like manner correspond with the habitual periods of the secondaries. Assuming, therefore, that the earth was once a vaporiform or gaseous body, occupying the space that includes the moon's orbit, it must have arrived at its present density and diversity of materials by slow degrees, and by the combined effects of heat, cooling, crystallization, and volcanic action, and to these must be added the electric force.

118. In what order the first operations occurred we have no positive means of judging; most probably the purely gaseous forms of matter were first evolved. Aqueous vapours must have been an early product; chemical combinations of metallic elementary atoms would succeed; but when the process of cooling became one of the formative agents, we have the first positive evidence of what at that period must have been the primitive form of the solid crust.

119. This primitive form is recognized in the rocks which form the greater part of the earth's surface. From the lowest depths yet known, to the highest mountain-peaks in all quarters of the globe, the granite form of rock is the most universal. Under the generic term granite are included all crystalline aggregates of quartz, feldspar, and mica. Associated with the granite as primary rocks, are syenite, porphyry, hornblende, gneiss, serpentine, and basalt. These are crystalline, and bear every appearance of having been formed from a state of fusion. Viewed as a whole, they are chiefly oxides of elementary substances. These are chiefly aluminium, potassium, sodium, calcium, magnesium, iron, manganese, and silicon. Sulphur, boron, lithia, and fluorine enter into their composition also, in a minor degree. Silicon bears the largest proportion in the formation, silica being reckoned as forming 45 per cent. of the earth's crust.

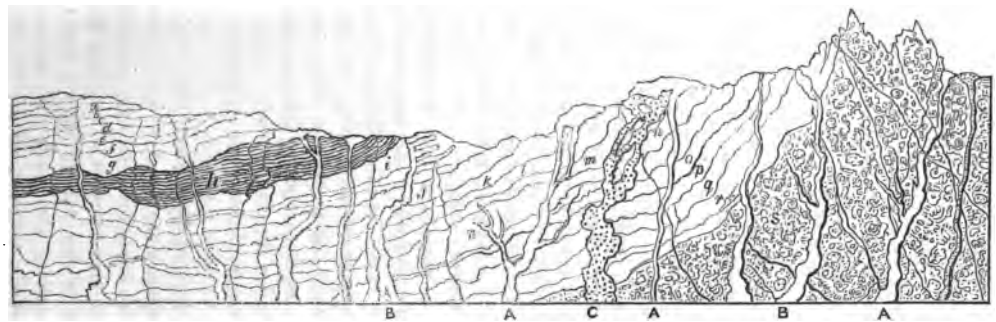
120. Superimposed upon this primitive foundation are found various strata of rocks. The earliest of these appear to be formed of the material of the primitive rocks, but now changed into new forms and combinations. Water and the atmosphere seem to have induced the same active changes upon the solid newly-formed rock as occurs in the present day. In time, the rock worn down, and the particles being carried into the neighbouring depths, were deposited and became the components of the earliest stratified rocks,—the slate system.

121. The next stratum and class of rocks includes the limestone and sandstone. In this bed is found the carboniferous deposits or coal formation. Upon this structure, calcareous formations, with sands and clays, and detached masses of rock-salt and alabaster are found. Then beds of chalk, with distinct varieties of clays, sandstones, and gravel. These last, with the remains of vegetable and animal organisms, constitute the upper layer of the earth's surface or crust.

122. It must not be supposed that these varieties and orders of strata are regularly and horizontally disposed; on the contrary, they lie in an inclined plane to the surface, with the appearance of having been thrown by violence into their various positions. This inclined order again is sometimes disturbed by fissures, filled up with the original granite, or with gravelly formations placed vertically. Interruptions of metallic veins also occur (fig. 11).

123. In the strata formed by the earliest and lowest of the sedimentary deposits are found enclosed the first evidences of matter that existed in a living form. These mineral masses enclose the remains of organic beings, vegetable and animal, which existed during the times they formed the surface of the earth. These organic forms consist of seaweeds, polypes, corallines, crinoids,

Fig. 11.—Section of the Strata of the Earth.



a Chalk.
b Green sand.
c Purbeck.
d Variegated marl.
e Shell limestone.
f Variegated limestone.
g New red conglomerate.
h Great coal formation.

i Mountain limestone.
j Old red sandstone.
k Ludlow rock, shale, and sandstone.
l Wenloe and Dudley limestone.
m Quartz rock.
n Clay slate.
o Hornblende slate.

p Chlorite limestone.
q Primary limestone.
r Mica slate.
s Granite.

A Greenstone.
B Trap.
C Porphyry.

graptolites, &c. Animals so near in form and appearance to vegetation that the rank of animalization can scarcely be conferred upon them. Contemporaneously with these existed some two or three tribes of mollusca. But however insignificant their rank may appear in the scale of creation, the polypes, from the commencement to the present moment, have always performed a most important share in the formation of the superficial figure of the earth. To them has been assigned the unremitting task of building up those extensive tracts of stony reefs called coral-banks. According to Professor Ansted, "They have built up 400 miles of barren reef on the shores of New Caledonia; and on the north-east coast of Australia their labours extend for 1000 miles in length; and these reefs may average perhaps a quarter of a mile in breadth, and 150 feet in depth; and they have been built amid the waves of the ocean, and in defiance of its fiercest storms."*

124. These, however, of necessity, could not have been the first organizations that were called into existence by the first actions of the vital force. The oldest remains were of animals that must have required smaller and simpler organisms for their subsistence. These organisms were most probably of so soft a texture as to render it very improbable any remains of them could be preserved, although such is stated to be the case; but this statement is considered doubtful.

125. It would seem, from what we now know of the production of living organisms in the animalculæ, that this was the first vital arrangement of the animal form. One of the first principles that modern scientific research has established is, that there can be no rest to the active forces of nature, when once the conditions are established by which these forces can be manifested.

* Ansted's Ancient World.

Production and reproduction are incessant: from the commencement of life until death, no instant passes without some change taking place. From the moment the special vitality of an organism ceases, a new power appears to be awakened that reproduces from its decomposition myriads of other organisms, *peculiar* to the decaying substance. To produce this effect, air, moisture, and electricity, separately and combined, are indispensable. A cheese, left to decay, will be gradually converted into a mass of living mites; a human corpse into maggots. The late Mr. Cross, discovered that a current of electricity, conducted through distilled water, isolated from all other substances, would be followed by the production of a species of acarus (a kind of louse), similar to those of cheese, sugar, &c., and these animals make their appearance upon the edge of the water. Any kind of vegetable matter, left to decay in water in contact with the atmosphere, will be certain to produce myriads of animalculæ.

126. The very moment, therefore, that the heated atmosphere and the boiling seas had cooled to the point fitted for the production of living organic matter, germs of vegetation of the lowest orders must have started into life. Infusorial animalculæ followed upon their decay, and as new forms of organic life, vegetable and animal, were developed, they became the pabulum for the new existences. How the progression from inferior to superior forms was effected, is yet a hidden arcanum of nature; but that such progression did take place, from moss to man, there is abundant and conclusive evidence.

127. Modern observation of the aboriginal portions of the globe, tend to the conclusion that their vegetation and zoology are in accordance with a relative condition of soil and temperature; and the "ancient records," hoarded up in adamantine security for us to explore, inform us, that in the earlier centuries of ages, such

plants and such animals only existed that were fitted to exist in the then terrestrial conditions of the surface.

At this period of the earth's surface, when water was the predominant aspect, invertebrated molluscs were the lords of the creation: no fish denizened its vast expanse, but at its close a few small fishes, allied to the shark tribe, were introduced. Many of these extinct fishes are remarkable for their strange peculiarity of shape. This period contains a great variety of animal formation, but confined to the waters of the globe; and although it does not pourtray a gradual advance of perfection in structure, yet an accordance between the conditions of the earth and its inhabitants appears to be the rule.

128. The next change of terrestrial surface presents a preponderance of carbonate of lime over every other form of submarine deposits; and in the sudden abundance of vegetable fossils, indicating a greater surface of dry land, an almost universal tropical climate, with a luxuriant and redundant vegetation.

This, perhaps, to us is the most interesting of the ancient geological epochs: to this period we owe the enormous accumulation of vegetable matter, which, in the lapse of years and subjection to extreme pressure, has become one of the great media of civilization—coal. The trees that formed these beds were mostly ferns and calamites of gigantic proportions. Lofty forest trees were not wanting, with colossal palm-like trees. These beds of vegetable matter were irregularly deposited in the upper limestone and sandstone series, over the greater part of the earth's surface.

129. The zoology of this particular formation appears to be scanty: a few insects, some shell-fish, and footprints referred to birds and perhaps to reptiles; but not a fragment of a quadruped, bird, or reptile has been obtained from any of the carboniferous strata in any

part of the world. Molluscs and fishes are abundant; the latter, which hitherto were mostly of small size, were now gradually advancing in development towards the latter part of the period; and several new forms of strange aspect and gigantic size were introduced. One circumstance to be noticed is, the commencement of the great reptile formation; its advent indicated by the structure of the serrated fishes, of which one gigantic species, the Megalichthys (great fish) was an exemplar. The shark tribes had increased in numbers; some of them of large proportions.

130. Evidences of great disturbances of the surface at this period are manifest. Above the coal beds are found deposits of coarse gravelly matter, the "new red sand-stone," the débris of some sandy or granitic rock. "A dreary waste of sandy unproductive beds seems to mark the disappearance of land clothed with vegetation; volcanic eruptions have taken place, and their effect is seen in torrents of ancient lava, heaps of disrupted ashes, and rocks chemically changed by the extrusion of hidden vapours charged with gases."* The change upon the inhabitants of sea and land is remarkable; all the older forms have nearly disappeared: a new world appears to be created, supplying the gap produced by those mighty disturbances. Immediately before this took place, one of the principal groups of the higher animals—the reptiles—were introduced; small and insignificant as individuals, but foreshadowing the great development of these animals, which took place in the approaching period. Foot-prints are found upon what must have been the rippled sands of the sea-shore, of small animals bearing resemblance to those of tortoises, —some apparently of gigantic proportions; while one group—bearing a resemblance to an expanded human

* Ansted's Ancient World.

hand,—has been assigned to an unknown animal and designated *Cheirotherium*. Further research has discovered the teeth and other bones of a reptile which, it is considered, might have possessed extremities capable of impressing these foot-marks, and has been called the *Labyrinthodon*, (from the peculiarities of the teeth). This would be a frog-like animal as large as a rhinoceros.

Fig. 12.

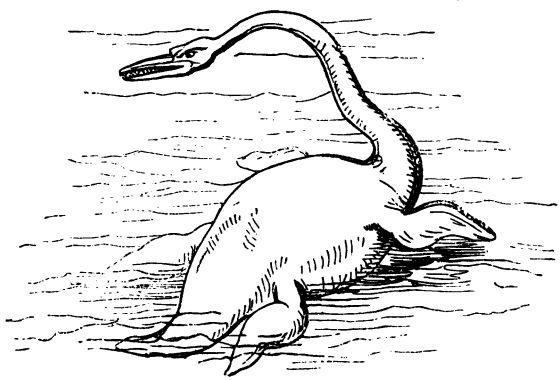
LABYRINTHODON.

131. A fine calcareous mud was the characteristic of the next aqueous deposit, called Lias, everywhere rich in organic remains. Some of the polyp family, several varieties of star-fish; some molluscs, one of which tribe —the Belemnite, was remarkable for their defensive inky fluid, some of which has been preserved with the fossil; and a peculiar variety of shark, similar to the existing species known as the Port Jackson shark.

But the most important of the remains of this epoch relate to the extraordinary forms of marine reptiles now extinct. A crocodilian reptile, the "Nothosaurus," seems to have belonged particularly to the land; but one group, the *fish lizards*, were exclusively marine in their habits.

The *Plesiosaurus* (like a reptile) with a body and paddles somewhat like a seal, and a swan-like neck, is one of the most singular and anomalous forms as yet met with. Its head, exceedingly small for its great length of body, but armed with numerous teeth, must have constituted a powerfully destructive and voracious animal. Its length must have been from ten to thirty feet (fig. 13).* A large and more powerful marine

Fig. 13.



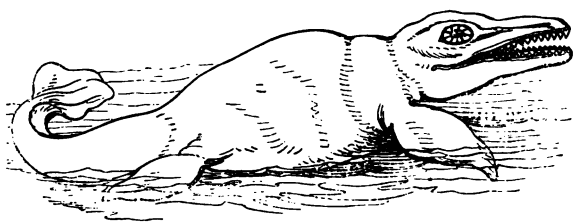
PLESIOSAURUS.

monster is seen in the *Ichthyosaurus* (fish-lizard); its length must have been from thirty to forty feet, armed with powerful jaws, of the same character as the crocodile and alligator; strong paddles similar to the plesiosaurus, but having the further advantage of a shark-like vertical tail (fig. 14). These characteristics must have rendered this monster the master and tyrant of the

* Fossil skeletons of the Plesiosaurus and Ichthyosaurus may be seen in cases 5 & 3, 3rd and 4th Rooms, North Gallery, British Museum.

deep. Its general form must have had a more fish-like appearance than the plesiosaurus; and may

Fig. 14.



ICHTHYOSAURUS.

be considered the analogue of the great existing tribe of marine mammalia, of which the whale is the type.

132. Connected with these forms, mention should be made of certain stony substances found in this deposit, designated by geologists, *Coprolites* (dung-stones). In some localities immense quantities have been found; they were the exuviæ of these animals. This is proved to be the case by their being found in situ in some of the fossil remains.

133. After the termination of this great deposit of calcareous mud, a great change seems to have taken place in the relative positions of land and sea; and in accordance with the before-mentioned law of agreement, the whole system of organic nature underwent an accompanying alteration. This has been called the Oolitic period. The successors of the polypes still bear the general family resemblance to those of the foregone ages. The crustaceæ yield forms similar to our lobster, prawns, and king-crabs of the existing seas. Univalve and bivalve molluscs abound; and various kinds of insects

have also been preserved. The fishes of this period were very abundant in number and kind; but, excepting the shark tribe, no very large remains are found. The reptiles of the Oolite include the ichthyosaurus; the plesiosaurus; many varieties of the crocodilian group; and a gigantic whale-like reptile, called the *Celiosaurus* (whale-lizard).

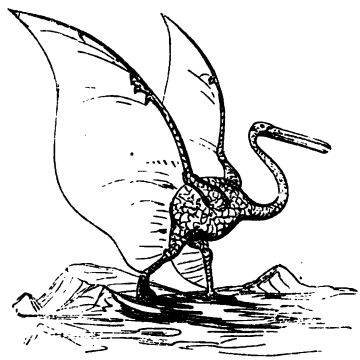
As before mentioned, the Oolite period indicates a change in the relative positions of land and sea. In the new red sandstone—the great marine Reptilian period—water appears to have formed the predominant surface; but now it appears retiring before the extrusion of land, and again is found a vegetation and terrestrial zoology. The vegetal fossils are chiefly, if not entirely, of the family of palms, found in the tropical and south latitudes of the present day. The land inhabitants were reptiles of truly gigantic character: the *Megalosaurus* (the great lizard), carnivorous, bulky in body, and standing high from the ground; that its weight was considerable is indicated by the strength of the bones of the vertebræ, and the mode in which they are massed together.

This reptile may be considered as forming a connecting link uniting this tribe to quadrupeds; most probably bearing some resemblance to the bulky and unwieldy form of the hippopotamus. Connecting the reptiles with birds, the Oolite furnishes a most extraordinary animal, called the *Pterodactyl* (wing-fingered), and is a true flying reptile (fig. 15). Some of the species attained the size of a cormorant; some not larger than a snipe. This animal was capable of swimming or sustaining a long-continued flight.

The quadrupeds of this period are small in size and marsupial in character. The companion reptile of the megalosaurus has received the name of *Iguadon*. This gigantic reptile must have been thirty feet in length,

and reaching a height from the ground of from twelve to fifteen feet. The teeth appear, from their formation, to have constituted a true vegetable feeding animal.

Fig. 15.



PTERODACTYL.

The *Hylæosaurus* was another land reptile of massive proportions and supported on long legs. Another monstrous vegetable feeding animal existed at this time, but the imperfect remains hitherto found, will not permit a judgment to be formed of its figure.

The constantly renewing and redundant vegetation of this period appears to have required these devastating animals to keep under its rapid growth.

134. The conditions of animal existence during the following or Cretaceous period differed from those obtained during the Oolite. The infusorial animalculæ bear in this formation a most important part. The invertebrata exhibited striking differences to those of the oolite series. Fishes were abundant; some of sauroid character but small in size; a vast number of sharks existed. The Reptilian remains of the cretaceous series are few, but in-

clude one new and gigantic marine lizard, the *Mososaurus*, the imperfect remains of a monster sauria, or—the *polyptychodon*, and remains of tortoises and turtles. The icthyosaurus, and pterodactyl are still found to be inhabitants, and the fossiliferous remains of birds, indicate a large species allied to the albatross. There is an entire absence of any remains belonging to land quadrupeds, or of the whale tribe.

135. Again, there are the characteristics of deep seas covering the greater portion of the surface. Volcanic and other disturbances appear to have put an end to the former distribution of land and water. By the elevation of districts, accompanied by the outbursts of quantities of lava, the ancient sea bottom of the cretaceous period became the basis of that distribution of land and water, which with subsequent deposits have resulted in the present one. These deposits of pebbly beds of sand, marl, clay, &c., upon the chalk, seem to have taken place with much regularity, but the elevating movements of the sea-bottom, appear again to have altered entirely the nature of animal life upon the surface. Most of the species found in the chalk deposits have disappeared and new ones supply their places. This new land became richly clothed with vegetation, and which bore a greater likeness to existing species than the older ones. It also appears that our northern climate in which it flourished, must have been more of a tropical temperature than the modern. Fishes abound, and present a nearer resemblance to the present type. Crabs and lobsters present a character similar to the existing species. The land reptiles exhibit evidence strictly in accordance wiih the molluscs, fishes, and vegetation. There are lizards, crocodiles, turtles and tortoises, with the addition of the new form of serpent. These last in the London clay, are of a tribe now represented by the boa-constrictor, and python, and reached

to twenty feet in length. The remains of birds are somewhat rare, but specimens have been obtained resembling the pelican, sea-lark, curlew, woodcock, owl and buzzard of the present day. The land quadrupeds seem to have been animals of the pachydermatous tribes: among these, some very nearly allied to the existing tapir; the size of the various genera varying from that of a pig to a rhinoceros.

136. The modifications of the surface of the earth from this period to the epoch of the present existing formation, were marked by successive changes in the animal and vegetal organization. Continued at long intervals of time, there does not, however, appear any division into distinct periods such as marked the ancient epochs; still the successive changes of animal form are very remarkable and distinct. In the older strata of this new arrangement the most striking animal form that occurs is the *Dinotherium*, a huge monster inhabiting swamps. Its length was nearly twenty feet, with remarkable tusks in the lower jaw; a vegetable feeder, and seems to have resembled the walrus. The climate of the northern latitude seems now to have changed. Accompanying changes in the vegetation produced vast forests of oaks, beech, and other modern trees. Huge monsters of the elephant tribe appear to have spread over a great extent of surface. The *mastodon* and *mammoth* belong to this family, and were inhabitants of the earth to the period immediately preceding the present. A most remarkable verification of this took place in the beginning of the present century, in the discovery of the entire body of an ancient mammoth on the shore of north Russia. This animal had been enclosed in a mass of ice which for ages had preserved it intact. The hairs, the skin and the flesh, were as perfect as if the animal had but recently died, and the latter served for a considerable length of time

as food for wild animals. The skeleton is now in the museum of St. Petersburg.*

During this period, (the one immediately preceding the present) new species of animals appeared: the rhinoceros, hippopotamus, several kinds of horses, large insectivorous animals, and a considerable number of carnivora; some of them of large size. The most important and interesting addition at this period was the introduction of the ruminant tribes; gigantic deer, and the aurochs, the progenitors of the tribes of domestic cattle. Marine mammalia in great variety were associated with new groups of terrene animals.

Quantities of remains of extinct animals have been found in numerous caverns in limestone rocks. These caves must have served for the dens of the animals there entombed.

Fig. 16.

DINORNIS.

In Australia an extinct tribe of wingless birds appear to have existed at a comparatively late period; the *dinornis*, varying in size, some being small, while others reached gigantic proportions. (Fig. 16). One representative remains (the *apterix*) but this also probably will soon be lost. Another bird, the *dodo*, inhabiting the Mauritius, has become extinct within the last two centuries. (Fig. 17.) In South America are found the fossil remains of a gigantic order of Edentata, represented by

* A skeleton of the mastodon can be seen in the British Museum.

the existing sloth, armadillo and ant-eater. The most remarkable of these fossils is the *megatherium*, (the great beast); an entire skeleton is possessed by the museum of Madrid—a restored cast of one is in the British Museum (north gallery). Its length is nineteen feet; massive and strong, it is formed to overcome the resistance offered by the largest trees, uprooting them to feed upon like the modern sloth. (Fig. 18). The *mylodon* and *megalonix*,

Fig. 17.

DODO.

Fig. 18.

SKELETON OF MEGATHERIUM.

were smaller than the preceding fossil, but belonging to the same family. One remarkable fossil of this

period exhibits enormous strength in the hinder extremities, which, though the animal could not have been larger than a Newfoundland dog, rivalled those of a rhinoceros. The *glyptodon* was a colossal armadillo. The *toxodon*, of which only the bones of the head and teeth are known, was a pachydermatous animal of giant proportions. The remains of another large species give the appearance of a camel, connecting the pachyderms with the ruminants.

137. This general sketch of the stratified arrangement of the elementary materials forming the upper surface of the earth's crust, sufficiently shows that in the course of time—in how many millions of years, it is impossible even to hazard a conjecture—its present tranquillity and orderly succession of vital production, must have been the result of many and fearful disruptions. That the internal cause of outward commotion has not yet entirely ceased, is evidenced by the occasional eruption of volcanic fire and molten material from various orifices on the surface of the globe. Also it would appear from experiments on artesian wells, that the temperature of the crust of the earth, increases on an average one degree for each ninety-two feet in perpendicular depth; so that if this increase of heat proceed in the same progression, at from five to six geographical miles, it would be sufficient to keep granite in a molten state. There is another point to be noticed—that the heat imparted to the surface by the periodical mean altitudes of the sun penetrates only to small depths. This outward source of heat, therefore, must have some point at which invariable temperature occurs: this in the northern latitudes is found at from fifty to sixty feet below the surface; while at the tropics it occurs at no more than at one foot. Reasoning upon this alone, the inference would be, that some universal cause of heat resided in the interior of the earth.

Most difficult is it for our powers of comprehension to conceive the boundary line between the interior fluid molten mass and the crust of the earth. From these facts, however, it may be concluded there are three kinds of motions of heat to be distinguished. The first, the heat derived from the periodical altitudes of the sun and penetrating from above downwards; the second, the heat derived from the sun at the equatorial regions, propagated slowly along the interior of the crust of the earth towards the poles, and there escaping into the atmosphere and space; the third, the slowest of all, derived from the cooling of the body of the earth; but so slow is this movement that it is inappreciable by any means we possess of testing it. It would seem therefore that the surface of the earth has arrived at a certain equilibrium of heat, intermediate between the red-heat of the interior and the cold of space, of the degree of which we can form no conception.*

VITALIZATION OF MATTER.

138. Certain elementary particles of matter become possessed of a power by which self-motion is produced among them, and when this is the case, these particles are said *to be alive*,—to have *life* or *vitality*.

How this power becomes in the first instance added to the inert material atom, it is impossible with our present knowledge to surmise; all that is known is, that certain atoms under certain circumstances manifest this self-action, and that this self-action being once commenced, the movement of growth becomes continuous. The elementary substances that enter into the composition of those forms of matter that put on or receive the power of motion called *life*, are gaseous—carbon, oxygen,

* See Buckland, Ansted, De la Beche, Humboldt, and Mantell.

hydrogen, and nitrogen, in various but certain definite proportions. This property or faculty of self-movement in certain forms of matter, constitutes the distinction of organic as opposed to inert or inorganic matter.

139. Organic matter constitutes two grand divisions in nature—vegetal and animal organization. Vegetal organization may be assumed to be the first stage from inert to life-moving matter, and this to form the basis of animal or *intelligent matter.*

VEGETATION.—VEGETABLE KINGDOM.

140. The first production and simplest state of living vegetal matter is in the form of a minute vesicle or cell, and it would appear there are two modes in which it originates,—either in the midst of an organizable fluid, or in the interior of a previously formed cell: the latter, however, may justly be considered a secondary formation or growth. There is some diversity in the form and structure of these primitive vesicles or cells; some of them are simply cavities surrounded by a transparent membrane, and of a more or less rounded form, varying from $\frac{1}{300}$ to $\frac{1}{500}$th of an inch in diameter. In general no visible openings can be detected in cells, although fluids readily pass into and out of them. Some are termed porous, from certain spots which appear like perforations, or pores; in others called fibrous, or spiral cells, there is a spiral elastic fibre coiled up in the inside of the membrane. A primitive cell being produced, appears to possess the power of developing others. The development usually takes place on one side, the new cell appearing in the form of a transparent vesicle rising from the surface; there is thus a constant multiplication of cells by a self-developing process. The external membrane of cells is composed of an unazotised substance called *cellulose;* and their interior is filled by a

mucilaginous matter, which undergoes changes in the process of growth. Each cell is formed to contain at some period of its existence a small body called a *nucleus*, in which there are often one or two minute spots termed *nucleoli*. These nucleoli are not always present. The nucleus is situated at different parts of the cell, sometimes free in the cavity, or imbedded in the substance of the membranous wall.

141. The union of these minute primary vesicles or cells, form what is termed cellular membrane or tissue, and often parenchyma. The membrane thus formed is permeable by fluids and becomes altered in the progress of growth, so as to acquire various degrees of consistence. In the advanced stages of growth, plants consist of two kinds of tissues, *cellular* and *vascular*, which under various modifications constitute their elementary organs. When cells are united by their extremities their partitions are occasionally absorbed so as to form tubes. Cells are united in a rectilinear manner, and sometimes communicate with each other laterally. Isolated cells occasionally have fine filaments or cilia developed on their surface. In the interior of some cells crystals are found; this appears to result from the alkaline matters, such as lime, potash, &c., absorbed from the soil and combining with oxalic, phosphoric, carbonic, and other acids. *Vascular tissue* consists of tube-cells, whose length exceeds their breadth.

142. The simplest and lowest forms of plants are those which consist entirely of cells—constituting their whole substance, and performing all the functions of life; they absorb and assimilate, thus performing the functions of nutrition and secretion; and, forming new cells, they reproduce new individuals like themselves. The plants so formed are called *cellulares*, or cellular plants. These plants comprise the sea-weed, the mushroom, and moss families.

143. The sea-weeds are cellular plants widely distributed over the globe, being formed in salt and fresh waters, in moist places, and even in hot springs. Sometimes they present, collectively, the appearance of green slime. Some of the species are gigantic, reaching in length 1800 feet; while others are so minute as to require the aid of a lens for their detection. About 2000 species have been enumerated.

144. The mushroom family, or *fungi*, consist of cells; sometimes round, sometimes elongated, in the form of filaments. Some fungi are limited to certain kinds of decaying matter. Peculiar species are developed in vinegar, in yeast, and in flour. The rapidity with which fungi grow is remarkable; a fungus has been noticed to shoot up three inches in the course of twenty-five minutes, and attain its full elevation of four inches in an hour and a half. Certain species give out a phosphorescent light. The various moulds which occur in bread, cheese, preserves, fruits, and books are plants of this extensive family. Some fungi are used as food, such as the common mushroom, truffle, &c. In France, Italy, Germany, and Russia, numerous fungi are used as food, which have acted as poisons in this country. Fungi cause disease in many plants: blight, mildew, and smut are diseases of grain produced by fungi; the disease called ergot, which attacks rye and other grains, and the dry-rot in wood are caused by fungi. 4000 species have been enumerated.

145. The mosses, or lichens, are found in all parts of the globe, adhering to stones, rocks, trees, &c. They possess the power of acting on hard rocks so as to disintegrate them in process of time. In the arctic regions, lichens supply food for animals. Iceland moss contains a large amount of nutritious matter.

146. When a more complex structure exists as in the higher tribes of plants, certain cells are appropriated

for absorption, others are concerned in assimilation, and others in forming and receiving secretions. When firmness and solidity is required, ligneous and woody matter is deposited, and woody fibre formed. Woody fibres consist of tubular cells thickened so as to give great firmness. The wood of trees is made up of fibres or tubes of this kind, and they are also found in the veins of leaves. The woody fibres may be separated from the cellular parts of plants by maceration in water; in this manner flax and hemp are produced. Linen is formed from woody tissue: cotton, on the contrary, consists of elongated cells or hairs. Woody fibre when reduced to small fragments, constitutes the pulp whence paper is made.

The unition of cells forms tubes, which again unite and form vessels for the conveyance of fluids.

147. When we ascend from the simple structure of the cellular plants, we find that the cellular arrangement is made to form compound organs that severally are concerned in the nourishment of the plant, and in the reproduction of new individuals. The first of these are called organs of NUTRITION: the second, organs of REPRODUCTION. A plant consists of a root, stem, and leaves; these form the organs of nutrition, and to them are added flowers and fruit, which are the organs of reproduction.

148. Roots are usually subterranean and colourless. The root gives off branches which divide into radicles or fibrils. They are composed of cells and vessels, which at the extremities of the fibrils become loose and spongy. In some instances, roots in place of being subterranean become aërial, as in the ivy and other climbing and parasitical plants, in which by root-like processes from the stem, they attach themselves to trees, rocks, walls, &c. When the root goes deep into the ground without division into branches, it is termed

a "tap-root," and this kind is frequently succulent and edible, as in the carrot, radish, and turnip.

149. The stem is that part of a plant which bears the leaves and flowers. Some plants are stemless, but consist wholly of expansions of cellular tissue: the sea-weed, mushrooms and mosses are plants of this description. Stems have usually considerable firmness and solidity, but sometimes are weak, and either lie prostrate on the ground, or climb by the aid of trees, rocks, &c. Stems have a provision for a symmetrical arrangement of branches and leaves; nodes or points whence branches are produced being placed at regular intervals. The manner in which the branches are given off from the stem give the character to the tree or shrub; the angles being more or less acute or oblique. In the poplar and cypress the angles are acute, and the branches are erect; in the oak and cedar they are spreading, forming nearly a right angle, while in the weeping-willow and birch, they are pendulous.

Plants which form permanent woody stems above ground, are denominated *trees* and *shrubs*, while those in which the stems die down to the ground and are not persistent are called *herbs*.

The stem has been termed the *ascending axis*, from being developed in an upward direction, and in contra-distinction to the root, which is designated the *descending axis*.

A stem is sometimes in the form of a *tuber*, which is a thickened stem produced by the approximation of the nodes. The stems of plants consist of a cellular and vascular system, the former including the outer bark and pith, the latter the inner bark and woody layers. In the early stage of growth the young stem is entirely cellular, but soon tubes appear, forming wedge-like bundles arranged in a circle round a cellular mass of pith, which is connected to the outer part, or bark, by

means of cellular processes or rays. As the stem grows and increases in firmness, further changes take place, by which its diameter is increased and rendered more dense.

The pith, or central part of the stem, is composed of cellular tissue, developed in an upward direction, the cells diminishing in size towards the circumference and being often hexagonal. In its early state the pith is of a greenish colour, and contains much fluid which is employed in the nourishment of the young plant. After serving a temporary nutritive purpose, it becomes dry and disappears. The woody fibres are deposited in concave layers or zones. The various appearances exhibited by wood and termed the grain, as in oak, mahogany, rosewood, fir, &c., depend upon the mode in which these layers are formed.

The woody layers vary in their texture at different periods. At first the vessels are pervious and full of fluid, but by degrees thickening layers are deposited which contract their canals, and sometimes obliterate them. In old trees there is a marked difference between the centre hard and the external hard wood. The hard or *heart-wood* is more useful and less liable to decay than the sap-wood. The wood of different trees varies in durability.

The bark lies external to the wood, and like it consists of layers. In the early state it is cellular and similar to the pith, but becomes developed into an outer and inner layer. Between the wood and bark there is a layer of mucilaginous semifluid matter, which is particularly copious in spring, and to which the name of *cambium* is given.

150. Leaves are expansions of the bark, developed in a symmetrical manner, as lateral appendages of the stem, and having a connexion with the internal part of the ascending axis. They appear at first as small projections of cellular tissue, continuous with the bark and

closely applied to each other. These gradually expand in various ways, acquire vascular tissue, and ultimately assume their permanent form and position on the axis. They may be divided into aërial and submerged leaves, the former being produced in the air, and the latter under water. Aërial leaves consist of vascular tissue in the form of veins or ribs; cellular tissue or parenchyma filling up the interstices between the veins, and of an epidermal covering. Leaves which are developed under water, differ in many points of structure from the former. They have no fibro-vascular system, but consist of a congeries of cells. They have no true epidermis but a layer of compact cells on their surface. A leaf in general consists of a flat expanded portion called the *blade* or *limb*, and the stalk; this last is sometimes absent. The leaf is usually horizontal, but sometimes vertical and occasionally twisted. In general there is one large vein in the centre of a leaf, which gives off branches as it proceeds, and these again smaller ones until a network of veins pervades the whole leaf. This form is not invariably adhered to, but in all modifications the principle of reticulation in the distribution of the veins is constantly observed.

Fig. 19.

Fig. 20.

The forms of leaves may almost be said to be infinite. They have been divided into simple and compound; a leaf is simple when it is developed symmetrically on each side of the stalk (fig. 19.); and compound when there are divisions in the leaf, forming, as it were, leaflets attached to the stalk (fig. 20). Leaves occupy various positions on the stem and branches, and in their arrangements follow a definite

order, some being arranged opposite each other on the stem, others alternately. In lichens, fungi, and algæ there are no true leaves.

151. The whole of a plant, root, stem, and leaves is covered by an external cellular tissue, and this is termed a general integument. Scattered over its surface are minute openings termed *stomata*. Certain projections are designated "hairs" and are variously arranged in different plants: sometimes they are hard in structure, and then are termed *aculei*, or prickles. Spines or thorns have a deeper origin. Cotton is the hair surrounding the seeds of the Gossypium herbaceum. Glands in plants are collections of cells forming secretions; they are formed sometimes at the base of the hair, the latter forming the duct conveying the fluid secreted. This is seen in the nettle and other like plants, and in these cases they are called *stings*. The fluids secreted by glands vary with the nature of the plants.

VEGETAL NUTRITION.

152. In order that plants may be nourished food is required, and as plants have not powers of locomotion it follows that their food must be brought to them by being universally distributed. The atmosphere and the soil accordingly contain all the materials for their nutrition.

The materials for food found in the soil are in a crude state, and enter the roots by a process of absorption or imbibition: it is then transmitted from one part of a plant to another by means of the circulation or progressive movement of the sap. It reaches the leaves, and is there submitted to the actions of light and air which constitute the functions of respiration, and thus the fluids are finally fitted for the process of assimilation, and form various vegetable products and secretions.

153. Plants are composed of certain elements which are necessary, and must be supplied for their growth; these are combined in various ways, so as to form what have been called organic and inorganic compounds. Carbon, oxygen, hydrogen, and nitrogen in various relative proportions, enter into the composition of the former, with sometimes a proportion of sulphur and phosphorus; while the latter consists of various metallic bases combined with gaseous elements and acids. In all plants there is a greater or less proportion of water; the relative proportions of all these constituents and water, vary in different species. By drying a plant at a moderate temperature the water is expelled, and by burning the dry plant its inorganic constituents are obtained.

The following table gives the proportions of the gaseous constituents in 1000 parts of a few familiar vegetable forms:

	WHEAT.	OATS.	PEAS.	HAY.	TURNIPS.	POTATOES.
Carbon	455	507	456	458	429	441
Hydrogen	57	64	61	50	56	58
Oxygen	430	367	401	387	422	439
Nitrogen	35	22	42	15	17	12
Ash, or inorganic matter	23	40	31	90	76	50

The proportion of water in 1000 parts of these substances is as follows:

Wheat	166	Peas	86	Turnips	925
Oats	151	Hay	158	Potatoes	722

154. Carbon is the most abundant element in plants; it forms from 40 to 50 per cent. of all plants usually cultivated for food. When united to oxygen in the form of carbonic acid, it is readily taken up either in the gaseous state by the leaves, or in combination with water by the roots. The soil contains carbon; in some soils, as those of a peaty nature, it exists in very large

quantities. The redundant carbonic acid is taken up by the terrestrial vegetation.

155. Water supplies oxygen and hydrogen: nitrogen is absorbed from the atmosphere and from decaying matters. These last during their decay, give off nitrogen combined with hydrogen in the form of ammonia.

156. These four elementary bodies are supplied to plants chiefly in the forms of carbonic acid, water and ammonia. In these states of combination they exist in the atmosphere, and hence some plants can live suspended in the air without any attachment to the soil. The other elementary substances entering into the composition of plants are chlorine, iodine, bromine, sulphur, phosphorus, potassium, sodium, calcium, magnesium, aluminium, silica, iron, manganese, and copper, variously combined with the gaseous elements forming sulphates, phosphates, silicates, chlorides, &c.

As soils must necessarily differ in the relative proportions of these inorganic materials forming the food of plants, it is evident that one soil may contain those necessary for the growth of certain species, and be deficient in those required by others. The knowledge of this principle forms the basis of agricultural chemistry. If a crop of wheat, oats, &c., have exhausted the soil by feeding upon certain of its constituents—lime, silica, &c., it becomes necessary to change the crop the next year, and also to add to the soil such manure as will contain those constituents the exhausted soil requires. The best manure would be, of course, the *crop itself*, burnt and reduced to the inorganic matters it took from the soil: in lieu of this, the next best manure would be that which contained the largest proportion of the required constituents. For this purpose lime,—decaying animal matter to furnish ammonia, nitrogen, decaying vegetal matter to supply the salts of metals, and phosphorus to form phosphates, are used with

animal exuviæ. To apply this principle justly and effectively, an analysis of the plant to be grown, the soil to be manured, and the manure to be applied should be made. The reason of this will be seen, when it is understood that some plants, as wheat, oats, barley, and rye, contain a large quantity of silica in their stems:—others, such as tobacco, pea, meadow clover, potato-haulm, and sanfoin, contain much lime; while turnips, beet-root, potatoes, Jerusalem-artichoke, and maize, have a large proportion of salts of potash and soda in their composition; so that although a crop of any particular plant may have exhausted the soil of its own peculiar food, another plant may still find its requisite pabulum; hence the necessity of rotation, or changing of crops from year to year.

157. While the leaves and other aërial organs of plants have the power of absorbing fluids, it is chiefly in the roots this process takes place. The cells of the fibrils of the roots are covered by a very delicate membrane which allows the imbibition of fluids to proceed rapidly. The nutritive materials of the soil are supplied to the roots in a state of solution.

158. The passage of a fluid through the walls of a membrane takes place when there are two fluids of different densities separated by the membrane, and this process has been termed *Endosmose*, when the current sets inwards, and *Exosmose*, when the current of transudation sets outwards. This process depends greatly on the chemical affinities between the fluids on each side of a membrane; on the porosity of the membrane, and the attraction existing between it and either of the fluids: it follows, therefore, that the nature of the parietes of the cells and vessels of plants must have a marked effect on their contents and secretions. If a tube, one end of which is covered by a

piece of bladder and partially filled with a solution of sugar, be immersed in a vessel of water, it will be found that a current of the lighter fluid, the water, will set in through the bladder and mix with the syrup; while a weaker current of the denser fluid contained in the tube will pass outwards.

159. The fluid matters absorbed by the roots are carried upwards through the cells and vessels of the stem, under the form of *ascending* or *crude sap;* they pass into the leaves where they are exposed to the influence of air and light, and afterwards return through the bark in the form of *descending* or *elaborated sap*, and a portion of them ultimately reaches the root, where it is either excreted or mixed with the new fluid entering from the soil. Gaseous matters are taken up by the roots and circulated along with the sap. Changes take place in the composition and density of the sap in its upward course, but the chief alterations take place in the leaves. There it is exposed to the influence of the light and air, by means of which carbon and hydrogen are fixed, oxygen is given off, and an exhalation of watery fluid takes place. The descending or elaborated sap is sometimes clear and transparent, at other times milky and opaque. This is called latex, and the transmitting vessels lactiferous.

The cause of the progression of the sap appears to be partly from the capillarity of the vessels, from the operation of endosmose, and from evaporation. The quicker or slower evaporation of the fluids on the surface of the plant will influence the degree of rapidity with which the sap is circulated. In clear and dry weather the evaporation will be greater than in cloudy, moist, or misty weather; hence plants kept in the dry atmosphere of rooms, fade from want of a due supply of fluid to compensate for evaporation. This process, by forming a vacuum, assists capillary attraction and atmospheric

pressure, and thus the fluids rise. When cut twigs or flowers are put into water, their functions are kept up for some time by endosmose and capillarity. Heat and light have a powerful influence on the movements of the sap, by promoting transpiration and the action of the cells. After the winter's repose, the first genial sunshine of spring stimulates the sap to activity; leaf-buds are put forth, the circulation of the sap increases, and the whole plant exhibits an active and vigorous existence. Towards the latter part of the season, when the heat and light decrease, the leaves perform their functions more languidly, and ultimately there is a cessation of the circulation.

160. The respiration of plants has a most beneficial influence upon the atmosphere, absorbing carbonic acid and exhaling oxygen, thus purifying the air and fitting it for the respiration of animals. This effect takes place only under the influence of light; in darkness no such decomposition takes place, or, rather, the process is reversed, oxygen is absorbed in moderate quantities, and some carbonic acid is given off: hence the presence of plants in sleeping-rooms must have an injurious effect upon their atmosphere at night.

VEGETAL REPRODUCTION.

161. The reproductive organs consist of the flower and its appendages,—the essential parts being the *stamen* and *pistil*. When the essential organs are conspicuous the plants are called flowering-plants; when they are inconspicuous they are called flowerless.

On examination it will be found that the organs of reproduction and nutrition are modifications of each other. The several parts of the flower may be all referred to the leaf as a type.

The inflorescence or arrangement of the flowers on the stalk takes place in two different modes: one clustering

on the stem or stalk in an indefinite manner,—flowers springing from points higher upon the stem or stalk; the other springing from the summit of the stalk in a single flower.

The flower consists of whorled leaves placed on an axis. There are usually four of these whorls:—1. The outer one called the *calyx;* 2. the *corolla;* 3. the *stamens;* 4. the most internal, the *pistil.* (Fig. 21.) When all the parts of a flower are separately developed, there is no difficulty in tracing this arrangement, but in many cases it is by no means an easy matter to do so, on account of changes produced by the union of one part to another. Of these four whorls the two outer, the calyx and corolla, are called *floral envelopes;* the two inner, stamen and pistil, are termed *essential organs.* In most cases the two outer whorls, the calyx and corolla, are easily distinguishable; the first being external and green, sometimes separate, and at others united to a greater or less extent. The corolla is generally the most conspicuous whorl, being usually more or less highly coloured, and frequently giving forth pleasant odours. It is composed of parts, disposed in one or more rows, termed *petals.* The structure of petals consists of cellular tissue, traversed by spiral vessels and tubular cells. The cells contain colouring matter, generally white, red, blue, or yellow, or some colour produced by an intermixture of these; seldom green, though occasionally this is met with. A corolla rarely consists of one petal, and when this occurs it depends on the non-development of others. The forms and

Fig. 21.

a, Calyx.
b, Corolla and petal.
c, Stamens.
d, Pistil and stigma.

modes of development of the corolla embrace great variety.

162. The *essential organs of generation* are the *stamens* and the *pistil;* the latter containing the seeds or germs of young plants, is termed the female, while the former producing a powder which appears to be necessary for fecundation, is termed the male. The presence of both is required in order that perfect seed may be produced. Sometimes the stamens and pistil are contained in the same flower, the flower is then hermaphrodite; sometimes the stamens will be found in one flower, the pistil in another, the flowers are then said to be universal, and are respectively *staminiferous* or *pistiliferous* flowers.

The cryptogamic plants, or cellulares,—the algæ, fungi, and lichens,—propagate their species by cellular development, consequently they have neither stamens nor pistils.

The stamens arise within the petals, varying in number from one to many hundreds. Like the other parts of the flower they are modified leaves, resembling them in their structure, development, and arrangement. A stamen consists of two parts, a threadlike portion termed the *filament*, and a broader one the *anther*, which contains a powdery matter called *pollen*. This consists of small cells developed in the interior of other cells, differing in form in various plants, being round in some, oval or flat in others. The length of the stamen varies with the nature of the flowers, whether erect or drooping, the object being to bring the anther into more or less immediate contact with the upper part of the pistil, so as to allow the pollen to be scattered on it. The pollen escapes from the anther through fissures or pores. Various bodies, such as glands, scales, hairs, &c., intervene between the stamens and the pistil; these constitute what is sometimes called the *nectary* in flowers. In the progress of growth it often contains saccharine matter. The *pistil* occupies the centre of the flower,

and is surrounded by the stamens and floral envelopes when they are present. It constitutes the innermost whorl, and after the flowering of the plant is changed into the fruit which usually contains the seeds. The pistil consists of two parts, the *ovary* or *germen*, containing ovules or young seeds; and the *stigma*, a cellular secreting body situated either immediately in the ovary, or is elevated on a stalk called the *style*, interposed between the ovary and stigma. Like the other organs the pistil consists of one or more modified leaves, which in this instance are called *carpels;* there may be one or more carpels, in which case each carpel has its own ovary, style, and stigma.

The ovary is usually of a more or less spherical form: it is sometimes free in the centre of the flower or united to the surrounding parts. The ovules are the bodies contained in the ovary and destined to become the seed.

163. Flowering takes place usually at a definite period of the plant's existence. It requires a large amount of extra nutrition, and its occurrence is accompanied with a greater or less exhaustion of the assimilated products; hence a certain degree of accumulation of sap is necessary that flowering may proceed.

Plants termed annual are exhausted after flowering, and die; but by retarding the flowering for two or more years, by nipping off the flower-buds, the sap accumulates, and, as in the case of the tree mignonette, they may be made to live and flower for several years. Many cultivated plants which lay up a large store of nutriment in the form of starch, lose it when the plants shoot out a flowering stem. This is exemplified in the case of the carrot and turnip, in which the succulent root becomes fibrous and unfit for food when the plants are allowed to run to seed. The period of flowering of the same plant varies at different seasons and in different countries. During the winter in temperate climates, and during

the dry season in the tropics, the vegetative process is checked; the assimilated matter remains in a state of repose, ready to be applied to the purposes of the plant when the moisture and heat again stimulate the vegetative functions. This stimulation occurs at different periods of the year according to the nature of the climate. Plants are accommodated to the climate in which they grow, and flower at certain seasons. There is even a periodicity in the hours of the day at which some open their flowers; some expand early, some at mid-day, others in the evening. Linnæus constructed a floral clock, in which the different hours were marked by the expansion of certain flowers. Some flowers open and decay in a day, and are called *ephemeral*. The expansion of flowers is regulated by light and moisture, and also by a certain law of periodicity.

164. The stamens and pistil are called the essential organs, because without them reproduction cannot be effected. The stamens prepare the pollen, which is discharged by the anther. The pistil is provided with a secreting surface, the stigma, to which the pollen is applied, in order that the ovules contained in the ovary may be fertilized. Various provisions are made for insuring the application of the pollen to the stigma; the comparative length of the stamens and pistils, their position, and opening of the anthers, are all regulated with this view. In some plants the stamens at a certain period of their development move towards the pistil, so as to scatter the contents of the anther. In the Vallisneria spiralis, a plant growing in the mud of ditches, the staminiferous plants are detached from the soil, float on the surface of the water, and produce there flowers and pollen; while the pistilliferous plants send up a long peduncle, which accommodates itself to the depth of the water by being spiral, and bears on its summit the flowers with the pistil. By these means the two

organs are brought into contact, and fertilization is effected. In certain plants the agency of insects is employed to insure fecundation. The length of time during which the pollen retains its vitality or power of fertilization, varies in different plants from a few hours to one or more years. If the pollen of one species is employed to fertilize the ovules of another, the seed will produce plants strictly intermediate between the two parents; these are termed *hybrids*, and are analogous to mules in the animal kingdom; the species, however, must be somewhat related.

Plants may be also propagated artificially by cuttings from the parent plant, and from tubers.

165. After fertilization various changes take place in the parts of the flower. The anther and stigma wither and decay; the floral envelopes become dry; the petals fall; the ovary becomes enlarged, and the ovules are developed as the seeds containing the *embryo plant*. The term fruit is strictly applied to the pistil or ovary with the seeds in its interior. The fruit is of various kinds; some are pulpy masses with the seeds embedded, as in the grape, gooseberry, strawberry, pomegranate, orange, apple, pear, &c.; some have but one seed enclosed in a hard case and embedded in the pulp, these are termed stone-fruit, such as the plum, peach, cherry, &c.; others again have a single seed enclosed in a dry woody husk, as nuts.

Leguminous fruits contain many seeds symmetrically placed in bag-like receptacles or pods; the pea and bean furnish examples. Some fruits are the produce of several flowers united, as the pine-apple, mulberry, &c.

Fruits are occasionally found seedless; but this arises from ineffective fertilization, or from age. The period of time required for ripening the fruit varies in different plants; most of them ripen their fruit within a year from the time of the expansion of the flowers,—some

come to maturity in a few days, others require some months.

166. While the pistil by the operation of the pollen becomes fruit, the ovule also is actively transformed, and when fully developed constitutes the *seed*. The seed contains the embryo with certain nutritive and protective appendages. The great object of fertilization is the formation of the embryo in the interior of the seed. In general one embryo is produced, but many plants produce seeds containing more than one. The embryo appears as a rounded cellular body enclosed in a sac, and attached to a filament called a suspensor. In this sac there is at first a mucilaginous fluid, the *amnios*, in which cells are speedily developed. The embryonic cell still attached to the sac by its suspensor, contains in the early state semifluid and granular matter which becomes organized, producing distinct nucleated cells. These gradually multiply and form a cellular mass, at first indistinct but afterwards showing a separation of parts—the rudiments of leaves. As the embryo increases in size it causes absorption of the cellular tissue in the embryo sac. In some plants the cells surrounding the embryo become filled with a deposit of solid matter, called albumen, consisting of starchy, oily matters, and nitrogenous compounds. It varies much in its nature and consistence, being farinaceous or mealy in cereal grains, fleshy as in the cocoa-nut, horny as in the date, ivory-palm, and coffee. The albumen is a store of matter laid up for the nourishment of the embryo.

The embryo consists of rudimentary leaves, a bud-like protuberance, the *gemmule*, which becomes the stem, and a rudimentary root or radicle. There is a marked difference in the number of rudimentary leaves, called *cotyledons*, in the embryos of plants, some having but one, others having two. This circumstance has been taken by botanists to characterize and form the divisions

of the whole vegetable kingdom, which is thus divided into three grand classes: the first containing the algæ, fungi, and lichens, termed *Acotyledonous* (without lobes); the second, *Monocotyledonous* (one-lobed); the third, *Dicotyledonous* (two-lobed). Great variety in the form of the embryo exists in these divisions, but in all the principle is the same—the embryo or germ being formed or developed as a new plant when placed in favourable circumstances.

167. The act by which the embryo of a seed leaves its state of torpidity and becomes developed as a new plant, is called *germination* (springing): the chief requisites for this process are moisture, air, and a certain temperature; this last varies in degree for different seeds,—some require a tropical heat, others thrive with a very low temperature. Although light is essential to the well-being of the plant, the seed germinates best in darkness. When all the requisites for germination are supplied, the seed becomes softened and swollen. The embryo passes through two stages of germination; the first in which it is nourished by the nutrient matter in store, the second in which it protrudes through the integuments, and the radicle descending to the earth it becomes an independent plant; the gemmule elongates, and seeking the surface becomes the stem, and is placed under the influence of light and air.

168. Plants, according to the duration of their existence, have been divided into annual, biennial, and perennial. The first of these run through their phases of existence within twelve months, and perish; the second do not produce their reproductive organs—flowers and fruit—until the second year, after which they perish; the third postpone the process of flowering and fruiting until the third year, or to any indefinite period. The difference of climate and cultivation may, however, alter all these conditions in plants. Some perennial plants live to a

great age. There are oaks in Britain planted before the Conquest; yews more than 3000 years old. The cypress, orange, banyan, and olive, often attain great longevity. A specimen of the baobah of Senegal (the monkey bread-tree) is said to be more than 5000 years old.

169. Cultivation causes great changes from the original condition of a plant: alterations in form and size, development of cellular tissue, and increase of starchy matter take place; this is seen in the case of turnips, carrots, potatoes, cabbage, lettuce, &c. Endless changes in the form and colour of flowers are also produced. There is always a tendency, however, never absent, to return to the normal or wild state.

170. The enormous amount of species of plants existing in all parts of the globe, upwards of 100,000 being already known, have naturally led to many attempts to arrange and classify them for the sake of convenience. Two modes present themselves: the first, a classification founded on the apparent external likeness of plants to each other; the second, an arrangement founded upon their structure and physiology. The first is strictly artificial, and can give little more than the names of plants, and can hardly be said to occupy a higher position in the science of botany than as an *index*. Linnæus in forming this kind of classification, took the essential organs of reproduction as the basis of his arrangement. The number, position, relative lengths, and connections of the stamens; the number of the styles, the perfection of the flowers, and the nature of the fruit, form the standards of his various classes, orders, and genera. The great disadvantage of such a classification consists in the necessity of a plant being in flower to determine its place in the system.

The second mode, or *natural system*, as it is termed, endeavours to bring together plants which are allied in

all essential points of structure as well as affinities, thus taking into account all their organs. Even this is, to a certain extent, artificial, and must be so until all the plants of the globe are known. To form this system certain species are grouped together, having an agreement in general structure and appearance greater than with any other species. This constitutes a *genus*. Several genera agreeing in more general characters, although differing in their special conformation, are grouped together and form an *order* or *family*. Orders having general characters in common are united in *classes;* genera, orders, and classes, are again subdivided, and upon this general plan all botanical classification proceeds.*

VEGETABLE CHEMISTRY.

171. The vegetable kingdom furnishes a great variety of organic compound substances, consisting essentially of a very few *elementary principles;* oxygen, hydrogen, carbon, and occasionally nitrogen, making up the composition of all vegetable productions, and on this account they are frequently capable of being converted into each other. Other principles, as sulphur, phosphorus, iron, sodium, iodine, &c., occur in minute quantities, and are of great importance in the natural vegetable products. From these primary and universal products, other substances, the results of chemical combination, are produced. The natural vegetal products are the following :—

Starch,	Gluten,	Oil,	Resin,
Sugar,	Gum,	Wax,	Acids,
Albumen,	Lignin,	Camphor,	Colouring matter.

172. One, if not the most important, of these primary natural productions is *starch*. It occurs abundantly in

* See the works of Professors Lindley and Balfour.

the esculent grains; in many roots, such as the potato and arrow-root; in the stems of some palms, known as sago, tapioca, and cassava. It is also found in unripe apples and pears; in the seeds of leguminous plants; and in lichens. It forms a large and important element in the food of animals. The ultimate elements of which starch is composed are, carbon 12, hydrogen 9, and oxygen 9; and as their proportions very nearly coincide with sugar, it is easily converted into the latter substance.

173. *Sugar* is found in variable quantities in the juice of many of the grasses; in the sap of several fruit trees; and in the roots of the beet and mallow. A variety of sugar, called *grape sugar*, is found in the grape, from which it takes its name; and is abundantly diffused through the vegetable kingdom. It is the sugar produced in honey, and is obtained by the insects from the nectaries of flowers.

The elementary components of sugar are, carbon 12, hydrogen 9, and oxygen 9, in nearly the same proportions as starch.

Unripe fruits contain a quantity of starch, which is converted into sugar by the process of ripening.

Sugar is obtained from the juices of vegetables by boiling them, with the addition of lime, to the consistence of a thick syrup, and then allowing the sugar to crystallize. The residual uncrystallizable syrup which drains from the sugar-refining moulds, is the dark viscous fluid known as *treacle*.

174. *Resin* is a vegetable product generally found dissolved in essential oils, and are then termed *balsams*. Common resin is obtained from the pine tree.

Caoutchouc, or India-rubber, is a substance somewhat analogous to resin, and is obtained from a species of fig tree. Gutta-percha is a kind of caoutchouc.

Amber is regarded as a fossil resin.

175. *Albumen* is found in many vegetable juices; and

in many seeds, such as nuts, almonds, &c. In its natural state it is soluble in water; but when heated it coagulates, and is then insoluble. Its component elements are, carbon 8, hydrogen 7, oxygen 3, nitrogen 1. Fibrine is a substance closely resembling albumen, and found in vegetable and animal substances.

176. *Gluten* is a substance found abundantly in association with starch in the seeds of the esculent grains; it is a modification of vegetable *fibrine*, which is a component of some juices, and is separated from them by coagulation. The elementary components are identical with it, and both bear a close analogy to albumen.

177. *Gum* occurs in almost all vegetable juices, and frequently exudes in drops from the bark of trees. It is generally transparent, tasteless, and soluble in water, forming a thick fluid, called *mucilage*. It is furnished plentifully by the acacia, and commonly known as *gum-arabic*. The cherry tree also produces gum very similar to the acacia. The gelatinous substance found in fruits and called pectine, appears to be closely allied to gum. Its elementary components are, carbon 12, hydrogen 11, and oxygen 11.

178. *Lignin*, or woody fibre, is the most abundant of vegetable substances, constituting about 95 per cent. of the different kinds of wood. It consists of equal parts of water and carbon. When wood is heated in close vessels and all substances driven off, leaving the carbon pure, it forms what is called *charcoal*. In nature, the crystallization of carbon forms the diamond; it appears possible that decaying lignin, under certain circumstances, might separate liquid carbon and thus be transmuted.

179. *Oil*, or oleaginous substances, are furnished in great abundance by various parts of plants. Oils are termed *fixed* and *volatile;* the former communicating a greasy stain to paper, which is not dissipated by heat;

the latter rise in vapours, and the stain communicated to paper disappears on the application of heat. Fixed oils are usually obtained from the seeds of plants by pressure, such as the almond, poppy, castor, linseed, and others. Olive oil is obtained from the pulpy flesh of the fruit. Essential oils are obtained sometimes by pressure from the rind of the fruit; sometimes by distillation from the bark, wood, flowers, and leaves of plants. Some oils acquire oxygen rapidly when heated, and acquire the property of drying: such oils are used in making oil-paint and printer's ink.

The component elements of oil,—carbon, hydrogen, and oxygen, are variously proportioned, according to the nature of the different oils.

180. *Wax* is a substance found in the pollen of flowers; in the envelopes of several kinds of fruit; and sometimes in the stems of plants.

181. *Camphor* is a substance which essentially may be considered as a solid oil: it is extremely volatile and inflammable. It is a compound of carbon 10, hydrogen 8, and oxygen 1.

182. *Acids* exist in vegetable juices; thus citric acid exists in the fruit of the orange, lemon, lime, red-currant, &c. Tartaric acid in the juice of the grape, and in the fruit of the tamarind. Malic acid in the apple, gooseberry, and mountain ash. Tannic acid in oak, bark, and nut-galls. Meconic acid in the poppy. Oxalic acid in the common and wood sorrel, and acetic acid exists in the sap of many plants. Vegetable acids are ternary compounds of carbon, hydrogen, and oxygen.

183. Colouring matters are furnished by nearly all plants, either directly or by process of extraction. Yellow may be produced from turmeric, arnotto, gamboge, safflower, saffron, and from some lichens.

Red from alkanet, dragon's-blood, madder, logwood, Brazil-wood, and from some lichens.

Blue from Indigo plants and from the flowers and fruits of many others. Green is the most abundant of all vegetable colouring matters, being found in almost all plants, and in all their parts, excepting roots. It is found to reside in the fluids of cells, and is developed under the direct agency of light. The name given to this matter is *Chlorophile* (leaf-green).

184. The art of dyeing is founded upon the affinity or attraction existing between colouring matters and the fibres of the fabric to be dyed. In woollen and silk this affinity is usually very considerable, and to such tissues a permanent colour is very easily communicated; but with cotton and flax it is much weaker. Recourse is then had to a third substance, which possesses in a high degree the required affinity, and with this the cloth is impregnated. This third substance is termed a *mordaunt* or *basis*:—the usual mordaunts are oxides of tin, iron, and alumina. By applying the mordaunt to the cloth by wood-blocks, or otherwise, patterns may be produced, as the colour may be removed by washing from the other portions. This mode is termed *printing*. Thus it will be seen that the art of dyeing is simply the knowledge of the chemical combinations of certain substances.

185. Among the secondary substances produced by chemical combination of the primary natural products of vegetation, the *vegetable alkaloids* constitute an isolated and very important group. They are met with in various plants, always in combination with an acid, and are considered to be the active principles of the plants from which they have been procured. They are obtained by chemical processes, in a crystalline form: they appear all to contain nitrogen in addition to the other usual elementary constituents, and have an

intensely bitter taste. The principal alkaloids at present known are the following:—

Morphia	from Opium.	Daturia	from Stramonium.
Cinchonin	,, Peruvian Bark.	Nicotiana	,, Tobacco.
Strychnia	,, Nux Vomica.	Conia	,, Hemlock.
Brucia	,, Ditto.	Aconita	,, Wolfsbane.
Atropa	,, Deadly Night-shade.	Digitaline	,, Foxglove.
Hyoscyamia	,, Henbane.	Emetina	,, Ipecacuanha.
Solania	,, Woody Night-shade.	Veratria	,, Hellebore and Colchicum.

In addition to these an analogous principle has been obtained from the poplar, pepper, asparagus, mezereon, gentian, rhubarb, coffee, and tea.

186. Another secondary class of substances produced by chemical changes of the primary vegetable products, is the result of the processes termed *fermentation* and *distillation*. When solutions of many vegetal substances are placed under certain circumstances, a spontaneous change takes place, and the result is, the production of an intoxicating liquor, or vinegar; the first constituting *vinous*, the latter *acetous* fermentation. The substance that forms the intoxicating ingredient of the vinous fermentation is *alcohol*, and this again requires distillation to separate it from the liquid produced by the fermenting process.

The principal substance concerned in vinous fermentation is sugar, and no vegetable juice can be made to undergo the process which does not contain it, or some other substance (such as starch) capable of being converted into sugar. A solution of pure sugar is not alone susceptible of vinous fermentation; it must have added to it some azotized substance that has in itself undergone or commenced the process of *fermentation* or putrefaction; and the substance most fit for this purpose is some form of *vegetable gluten* that has been changed by the contact of oxygen and water and become *ferment* or *yeast*.

In substances containing nitrogen, fermentation or putrefaction is spontaneously established when water is present, and the temperature sufficiently high. On the contrary, substances not containing nitrogen require, in order to their undergoing this metamorphosis, the presence of a nitrogenized substance already in a state of fermentation or putrefaction, and the form of "yeast" best supplies this requirement, although putrefying animal substances would excite the same action.

The atoms of yeast or ferment are in a continual motion; a certain quantity then being added to the vegetable solution containing sugar, communicates this motion until the whole quantity is brought into the same state of motion.

The changes that take place in the arrangement of the atoms are as follow: the carbon of the sugar is divided between the hydrogen and the oxygen; there is formed on the one hand a carbonized compound containing all the oxygen (carbonic acid), and on the other, a second carbonized compound containing all the hydrogen (alcohol).

This kind of decomposition is the same for all organic substances which putrefy or undergo a metamorphosis, it being understood that the products vary according to the composition of these substances.

187. *Wine*, properly so called, is exclusively obtained from the juice of the grape. The principal substances it holds in solution are sugar, gum, gluten, and bitartrate of potash. It easily ferments spontaneously at temperatures between 60° and 80°; grape-juice, therefore, does not require an artificial ferment or yeast, having in itself all the requisites for producing it. After the operation of fermentation its specific gravity is much diminished, its flavour changed, and has acquired intoxicating powers from the formation of alcohol.

Wines derive their colours from the husk or skin of the grape.

Perry and *Cider* are the fermented juices of pears and apples.

For the manufacture of *Beer* malt is required.

188. *Malt* is barley which has been made to germinate to a certain extent, and then the process stopped by heat. The barley is steeped in cold water and made into a heap upon the malt-floor; here it absorbs oxygen and evolves carbonic acid, its temperature rising. When the germination has proceeded to the required extent, its further growth is arrested by drying at a temperature slowly elevated to 150° or more.

Barley is supposed to lose about 8 per cent. by converting it into malt.

The following are the comparative analyses of unmalted and malted barley, showing the changes which take place in the operation:—

	BARLEY.	MALT.
Gum	5	14
Sugar	4	16
Gluten	3	1
Starch	88	69
	100	100

189. In the manufacture of beer, malt is ground and infused in water at a temperature of 160° or 180°. This infusion is called the *wort*, and consists of saccharine matter, starch, mucilage, and a small quantity of gluten. The wort is next boiled with *hops*, and the liquor then cooled to about 50° as quickly as possible. A proper quantity of yeast is then added, and the whole placed in a fermenting vat. In this vessel the different substances in solution begin to act upon each other; an intestine motion ensues, the temperature increases, and

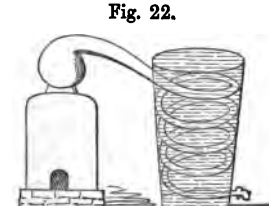
carbonic acid escapes in large quantities; at length the evolution of gas ceases, the liquor becomes quiet and clear; it has now lost much of its sweetness, has diminished in specific gravity, acquired a new flavour, and become intoxicating from the presence of alcohol.

190. *Alcohol* is the spirituous or intoxicating ingredient of all fermented liquors, and is separated from them by distillation.

When wine is distilled, the alcoholic liquor obtained is called *brandy*. When the juice of the sugar-cane is fermented and distilled the product is *rum*. The spirit obtained from grain is distilled from an infusion of raw grain, somewhat similar to the brewer's wort, but with this difference, that instead of pure malt, distillers employ raw, mixed with a small quantity of malted grain. The water is of a lower temperature than that required for brewing, but the starch of the barley is converted into gum and sugar by the longer maceration or *mashing*. Yeast is added to the wort. The spirit thus obtained is known as whiskey, and a modification of it is called gin.

191. The process of distillation is very simple. The liquor to be distilled is put into a vessel attached to a furnace, which raises the liquid to the boiling point; the vapour thus raised passes through a spiral tube immersed in a vessel of cold water; this cools and condenses the vapour in its passage, and the condensed fluid is received from it. This apparatus is called a *still* (fig. 22). The vapour of alcohol being lighter than that of water passes over first, and when the whole of the spirit has passed over the process is stopped. As

Fig. 22.



a portion of the aqueous vapour necessarily passes over with the spirit, a second or third distillation is required to render the spirit pure.

If *absolute alcohol* is required, or *anhydrous* (without water), some substance is added which has a strong affinity for water, such as carbonate of potash, chloride of lime, or sulphate of soda; these eagerly absorb the water, but are inadequate to the total abstraction of it. Pure alcohol is a limpid colourless liquid, of an agreeable smell, and a strong pungent flavour. The specific gravity of the purest alcohol is ·791; as it usually occurs it is ·820 at 60°.

Equal parts of anhydrous, or absolute alcohol, and water, constitute *proof spirit*.

It will be thus seen that a *brewery* and a *distillery* are, in fact, chemical laboratories.

192. Panary, or bread-fermentation, is essentially vinous; yeast added to a mass of farinaceous meal and water, converts the small quantity of sugar the meal naturally contains into alcohol and carbonic acid. The gas thus disengaged mechanically separates the particles of meal, and with the heat of the oven produces a spongy texture, and also dissipates the alcohol.

193. Any liquor that has undergone the vinous fermentation, when exposed to the access of air with a temperature above 60°, is altered in its constitution by a new fermentation in which oxygen is absorbed, carbonic acid evolved, and the alcohol gradually uniting with the oxygen passes into *acetic acid*, or *vinegar*. This is termed *acetous fermentation*. The vinegar, or acetic acid, thus produced, contains many impurities, but by distillation and re-distillation, acetic acid of great strength and purity is obtained.

The destructive distillation of wood in closed iron vessels produces *pyroligneous acid*, which by further distillation is purified from the tar and other matters

that pour over, and can then be used as household vinegar.

Acetic acid exists free, and combined with lime and potash, in the sap of many plants.

It unites with many of the alkalies, forming acetates.

194. When alcohol and sulphuric acid are mixed and distilled, the product is a highly volatile colourless liquid, known by the name of *ether*. The properties of ether are very remarkable. It is a solvent generally for all oily and fatty substances. Its component elements are carbon 4, hydrogen 5, oxygen 1; its specific gravity at 60°, is ·720. It boils at 90°.

195. *Bitumen* is a substance bearing considerable resemblance to oily and resinous bodies, and is formed abundantly in nature in situations that render it probable that it has been the result of subterranean igneous action upon organic formations. Thus it is contained in coal; and in certain parts of the world there are wells or springs in which the liquid bitumen is constantly rising to the surface. There are several varieties or modifications of bitumen, of which naphtha, petroleum, tar, and asphaltum are the principal.

Naphtha is a combustible liquid, of a yellowish white colour; it occurs in considerable springs on the shores of the Caspian Sea, in Sicily and Italy; and is also obtained by the distillation of tar and coal. It is a binary compound of carbon and hydrogen.

Tar is obtained from the common pine, or Scotch-fir, by distillation. When inspissated it is called pitch.

Petroleum (or rock-oil), so named from its having been found dropping from rocky fissures, and issuing from the earth, appears to be naphtha in a thickened and inspissated state.

Asphaltum is found abundantly on the shores of the Dead Sea, in Albania, and in the West Indies. It was one of the materials used by the ancient Egyptians in

embalming, hence termed *mummy-mineral.* At Babylon it was used for mortar.

Kreosote is a substance obtained from the distillation of tar. When quite pure it is unalterable by exposure to air. It consists of carbon, hydrogen, and oxygen. This substance is remarkable for its extraordinary antiseptic powers. A piece of animal flesh steeped in a very dilute solution of kreosote dries up to a mummy-like substance, and is incapable of putrefaction. The well-known efficacy of impure wood vinegar in preserving provisions, is due to the kreosote it contains; and the effect of wood smoke for the same purpose is also thus explained.*

ANIMALIZED MATTER. THE ANIMAL KINGDOM.

196. The next combination of matter to be noticed and which naturally follows upon vegetation, is Animalization—the Animal kingdom.

At first sight nothing appears more easy and simple than to define the boundary existing between the vegetal and animal kingdoms; nevertheless there is no question in natural philosophy so difficult to answer; nor any fact more difficult to decide. Linnæus divided created matter into three kingdoms, and characterized them as the "*Mineral*, or un-organized;—the *Vegetable*, organized and living;—the *Animal*, organized, feeling, and moving spontaneously." The advancement of the knowledge of organization no longer permits this definition in its strict sense; and has, indeed, rendered the difficulties of separation in the lowest forms insuperable. It appears easy to describe a plant as an organic being fixed to the earth; and an animal, in contradistinction, as an organic being with the power of locomotion. But some vegetal organisms move freely from place to place,

* See the works of Brande, Turner, Graham, Liebig.

and many species of animals are as firmly fixed to their allotted spot of earth as the firmest oak. The spore-cells of some of the sea-weed family, and many microscopic single-celled plants, have a rapid locomotion; while most of the plant-like polypes, and the oyster—an animal advanced in organization—are affixed to the rock upon which they first became developed. The distinction of locomotion, therefore, will not serve as a boundary between the two kingdoms. It may be asked, is there any real or marked difference that will afford a certain guide to the distinguishment between a vegetable and an animal; and what is there that can be taken to mark the boundary that separates the two kingdoms, and enable the naturalist to say where one ends and the other begins? In truth, there is no *absolute* boundary between them. As far as regards the more obvious members of both kingdoms it is easy enough to distinguish them; but in the lowest forms, the vegetal glides so imperceptibly into the animal domain, it is impossible to determine the precise boundary between them. "Animals and plants are not two natural divisions, but are specialized members of one and the same group of organized beings."—(Owen's Lectures).

But if we have not a mathematical precision of boundary-line, there are some distinctions in the broad aggregation of the two classes which sufficiently serve the purpose of discriminating one from the other. For instance: vegetal organisms derive their nutriment solely from the inorganic kingdom; while on the contrary, all animals must have their nourishment in the form of organisms: here then is a constant and appreciable difference. It may therefore be said, that plants are nourished externally,—animals internally: the root, characteristic of the one,—the stomach of the other.

When we rise higher in the animal scale, we perceive the existence of another distinction; a new form of

structural development, the function of which is, what is understood by the terms *intelligence* or *instinct*. Vegetables possess no will or determination that can guide or alter their mode of existence; they must perforce exist according to the circumstances in which they are placed: if these be favourable, they flourish,—if unfavourable, they die. Some animals it is true, as mentioned above, are as dependant for their supply of food in their permanently fixed position, as plants; but even in these vegeto-animal existences there is an amount of intelligence or instinct that enables them to allure and seize their prey.

This intelligence, up to a certain rank in the scale of animal creation, is but sufficient for the procuration of the means of subsistence, and it will be seen that for this purpose merely, the *intelligent structure* is simple; but when higher powers are to be manifested, then more complex organs of intelligence are developed, and these in a direct ratio with the necessity for intelligence, and the rank of the animal in the scale: this structure, therefore, forms a natural and obvious distinction between the two kingdoms. Another, although not quite universal, difference exists in the circumstance that plants absorb carbon and emit oxygen; while animals absorb oxygen and emit carbon.

197. It was stated (par. 140), that "the simplest and earliest form of vegetal organization was a minute vesicle or cell, and that it originated either in the midst of an organizable fluid, or in the interior of the previously formed cell."

This also strictly applies to the first development of animal life. It commences with a cell-formed animal, and from it progresses by cell-growth to the highest forms of animal life.

It has been shown by laborious research, "that the entirety of the structure of an animal originates from

a single cell; that this cell gives birth to others analogous to itself, and these again to many future generations; and that all the varied tissues of the animal body are developed from these, although no difference can be, in the first instance, observed among them."—(Carpenter's Physiology).

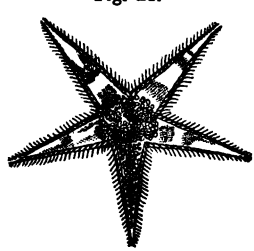
Every portion of the animal body, whether bone, muscle, skin, &c., is built up and formed by the aggregation of these minute vesicular forms, as was described to be the case in the structural organization of the vegetable kingdom. How inorganic elementary matter becomes imbued with the property of self-motion or *life*, is a mystery which our present knowledge cannot permit us to solve. It is perhaps possible, future research and experiments may lead to the knowledge that the addition of *vitality* to inorganic matter is the result of a chemical law,—perhaps a modification of the universal law of attraction controlled by electricity. This is certain:—that the *formative force* of animalization must have a certain controlment is evident in the similitude of forms derived from a common parental source.

198. As general characteristics, subject to some exceptions, and these only in the lower forms, animals may be said to consist of a head, a body, an internal apparatus to receive and digest food; with organs of locomotion fitted for the condition in which they may be placed, whether as aërial, terrestrial, or aquatic animals.

199. Very early endeavours were made to classify the members of the animal kingdom; but as some external and arbitrary characters were generally selected to associate the various groups, this selection generally resulted in the incongruous assemblage of essentially different animals. Until the time of Cuvier the animal kingdom was divided into two primary groups:—the Vertebrated and the Invertebrated. It was found that the vertebral column was subordinately an exponent of

a most important structural system—the nervous system. Those animals, therefore, possessed of a jointed spinal column were termed Vertebrata (from the Latin word *verto*, to turn); and all those that were destitute of this support, In-vertebrata. It was shown, however, by Cuvier, that many of the latter class contained types of organization as distinct from each other as any of those are from the vertebrata. He proposed, therefore, to divide the animal kingdom into four primary groups: the lowest order of which he termed Radiata; the next in rank, Mollusca; the third, Articulata; and the fourth or highest class, Vertebrata. Modern zoologists have recognized and accepted this division.

Fig. 23.



STAR-FISH.

200. The *Radiata* he so named because most of the species comprising this class of animals have their parts arranged round a centre. This character of radial, or circular symmetry, is in no instance better seen than in the common star-fish (fig. 23). The mouth placed in the centre of the disc leads to a stomach which occupies the greater part of the body, and sends radiate prolongations into each arm or ray of the fish.

201. *Mollusca*, (soft-bodied) as the name implies, are characterized by softness of body, absence of bony skleton, and indefiniteness of form, more especially in the lower groups. But although many of this class have naked soft bodies, in a large proportion the surface has the power of exuding shelly matter, so as to form a protective habitation, within which the animal can withdraw its body. This shell, however, must not be taken

as a skeleton of the animal. The common slug is an exemplar of a naked molluscous animal; and the snail, with its shelly habitation, may be taken for the other.

202. The *Articulata* (articulated animals) are distinguished by an external hard covering, divided into several pieces, jointed or articulated together by a membrane in such manner as to allow of free motion. The lobster, centipede, and beetle, from their articulated coverings, are members of this class.

203. In the three preceding divisions the nervous system is comparatively simple in its structure; the various animals composing them appearing to hold their existence subordinate to the two functions of nutrition and reproduction; but with the *Vertebrata*, the nervous system attains a development that renders it superior to these mere vegetative functions. This class of animals has an internal bony skeleton, from a portion of which —the vertebra, or spinal column—this division takes its name.

204. The most minute, if not the lowest organised forms of animal life, are to be found in the Animalculæ or Infusoria. Were it not for the wonderful power of the microscrope, we should be ignorant of even their very existence. Wherever, on the surface of the earth, vegetal matter is found decaying with moisture, these animal atoms are certain to be present; hence they have been termed as a class, Infusoria. Their minuteness is extreme; the smallest of the species—the *monad* —being estimated at $\frac{1}{2000}$th of a line in diameter (a line being the $\frac{1}{12}$th of an inch). Of such species a single drop of water may contain, according to Professor Owen, "500,000,000 of individuals, a number equalling the whole population of the globe." Considerable difference of size prevails, as in the case of all other classes of animals, the difference between the minutest monad and one of the largest species is very great. Great

differences also exist in form, as well as structure, in these minute beings: some are simple naked bags of membrane, either smooth or ciliated; others are covered with a shell formed of silex, in many instances of a complicated and beautifully arranged pattern. Most of these swim freely in their parent fluid, but some are attached by a long contractile peduncle to foreign bodies.

The simplest of these microscopic forms of animal life are called *Polygastria* (many-stomached); others further advanced in organization are called Rotifera (wheel-like), from the apparently wheel-like motion with which they progress. It is occasioned by the rapid vibration of hair-like filaments, or cilia, which serve as instruments of locomotion, and for the prehension of food. Although many of these tribes voraciously prey upon each other, their chief sustenance appears to be the decaying particles of vegetal and animal matter, in their progress of change from organisms to their inorganic elements. On this account, and from the universality of their presence on the surface of the globe; their incredible numbers and insatiable voracity; Professor Owen believes that these minute animal forms are means of purification, by arresting the change of organic matters into their inorganic elements: they are thus returned into the great circulating stream of life, and he terms them "the scavengers of the globe."

205. A large class of animals, as low in organization as the preceding, consists of beings developed within the bodies of other animals, and existing entirely at the expense of their solids and fluids. The number of these parasites is very great; and some idea of it may be conceived when it is stated, that almost every known animal has its peculiar species, and generally more than one: the human body is infested with eighteen kinds of parasitic animals.

This class is termed *Entozoa* (within-animals).

The organization of the lowest forms of these entozoa is more simple than is presented by the lowest infusorial; but in some of the higher forms there is great complexity in the anatomical structure. These animals are known by the general term, *intestinal worms;* but the intestines are not the only locality in which they are found, almost every organ having its peculiar worm,—including even the eye. Neither are they invariably vermiform: the hydatid (common to man and other animals) is a simple bag containing fluid, and varies in size from a pea to that of a child's head. The tape-worm, the round-worm, and thread-worm are common, and well known as infesting the human intestine. There is a variety of tape-worm which appears to be confined to the inhabitants of Russia. How the larva or eggs of these animals first obtain admittance into the cavities and tissues of the body is not known. It is supposed by some, they become developed in some of the lower animals, and taken into the stomach as food. The genera and species of this class are numerous. They are generally soft and colourless.

206. The next class of radiated animals is one widely diffused over the globe, the *Polypes*, a name given by the ancient Greek naturalists to the common cuttle-fish; and from a supposed general resemblance, this class has been grouped under the common name of *Polypia*. A polype presents a soft, cylindrical, oval, or oblong body, with an aperture at one end of its extremities, surrounded by a coronet of long tentacula or feelers. In most of the class, the aperture leads to a single stomach without intestine. In the higher organized members, the stomach is prolonged into an intestinal canal, terminating with a distinct anal opening. The organization of the polypes is, in general, simple; and many members of this class possess an affinity with the vegetable kingdom. The sea-anemone, for instance,

presents an appearance so much like composite blossoms, that the species have been commonly termed *Animal-flowers.*

The family of Polypi include several genera: the *Hydrozoa* (freshwater polype); the *Anthozoa* (animal-flowers); the *Bryozoa* (moss-animals).

Fig. 24.

HYDRA.

207. The *Hydra* (fig. 24), of which there are several species, marine as well as fresh-water, is a naked free-swimming animal, extremely voracious and prolific. These minute animals abound in fresh water, and in the seas surrounding our shores.

208. The *Anthozoa* form a fixed compound body, somewhat resembling the form of a tree with its branches and blossoms (fig. 25); each animal being independent of the others, but forming a member of this compound community. The common trunk consists essentially of a ramified tube of either horny or calcareous matter, fed in common by the actineal activity of the little beings forming the community. In some cases the calcareous matter is deposited in the form of rounded masses, commonly called *brain-stones*, from their similitude to the form of the human brain. The substance called coral, is the horny skeleton of a species of polype hardened by exposure to the air. However insignificant these creatures appear to be, the combined powers of some of the species have importantly influenced the modifications of the crust of the earth, (par. 121).

Fig. 25.

ANTHOZOA.

209. The *Bryozoa* form a class, the most part of which are microscopic; but from their aggregation, form masses of living matter. The common substance called *sea-mat*, which incrusts marine bodies, is a familiar example. There are many varieties of this family; some of which, although so minute, are complex in their organization.

Many species of polypi, in their larval state, are locomotive; but in their change from the larval to their polypoid condition, become the fixed beings they have been described.

210. The class called *Acalephæ*, or *sea-nettles*, comprehends some of the most singular members of the animal kingdom. They are swimming gelatinous animals with transparent tissues, having the power of stinging, from which circumstance is derived the name *Acalephæ*, or nettles. There are many varieties of this class; one of which, the *Medusa*, is common to all seas, and familiarly known as *sea-blubber*, *jelly-fish*, &c. Some species move by aid of bands of cilia; others are moved by the wind acting upon a portion of their body exposed to its influence. It is stated by some observers, that these animals commence their lives as infusorials—their progress to the form of polypi before becoming ultimately the mature animal.

211. The *Echinodermata* (spiny or thorny-skinned) have a more complex structure, and form the highest class of Radiata. They are inhabitants of the sea: and, as their name implies, have rough skins, some being armed with prickly spines. Of this class there are several orders, with subdivisions of distinct families. Of these, the *Crinoidea* (lily-like or stone-lilies), is an almost extinct polyp-like animal, fixed upon a jointed stem. Some of the species are fixed; others are liberated and move freely in their adult stage. The *Asteroidea* (star-fishes) are free, and contain many varieties. The

Echinoidea (sea-urchins) have spheroid bodies encased in a crust of calcareous plates armed with spines. The *sea-hedgehog* is enclosed in a spiny globular shell. The *Holothuria*, or sea-cucumbers have flexible integuments with scattered calcareous corpuscles. Closely allied to the holothuria is a marine vermiform animal, the *Sipunculus*, which burrows in the sand.

212. The animals next in order of organization are those forming the class *Annulata*; characterized by soft bodies symmetrically annulated. There are several orders and genera of this class, the principal of which are the leeches, earth-worms, sea-centipedes, sea-mice, &c. The body of a worm is generally soft, long, and subdivided into a number of segments, for the most part resembling each other. In the lowest forms the locomotive organs are suctorial discs, the suckers being two in number and terminal in position. This is seen in the mode of progression of the common leech.

213. A class of vermiform parasitic animals, attached to the bodies of fishes, has been termed *Epizoa* (upon-animals).

214. Another class of animals, many of them parasites, is called *Cirrhipedia* (curled-footed), from the curled filamentary appendages with which they are provided. The barnacle and sea-acorn shells are examples of this class.

215. The Crustaceous animals are aquatic, and provided with strong calcareous shells to protect them from injury. These shelly skeletons are articulated in segments; but being from the nature of the material, inelastic, and not endowed with powers of growth, the animal has to cast its shell at certain periods, and a new one is secreted by the covering, or lining membrane. They are provided with locomotive organs in the form of feet, and have a powerful jointed tail which assists them in progression. In this class the organiza-

tion is more complex in structure than the preceding classes. The lobster, cray-fish, crab, &c., are types of this class.

216. The *Molluscous* tribe, so called on account of the soft unjointed nature of their external integument, bears, in some of their characteristics, a similitude to the polype tribe. In a large proportion of the lower organized mollusca, there is no head and no brain; the inlet for food is simply a gullet without jaws, tongue, or mouth, properly so called. All other mollusca are provided with a head, which generally supports feelers or soft tentaculæ; eyes, and a mouth armed with jaws. The mollusca may, therefore be divided into those without and those with a head. The *Acœphalous*, or headless, are all aquatic, and are divided into classes according to the modifications of their integuments, or of their gills. These are the *Tunicata* (cloaked animals) with a soft gelatinous integument. The *Brachiopoda* (arm-footed), defended by a bivalve shell, one valve of the shell being applied to the back, the other to the belly of the animal; which is attached either by its shell, or by a pedicle to some foreign body.

The *Lamellibranchia* (plate-like gills) are bivalve shell fish with gills in the form of vascular plates of membrane. One valve is applied to the right, the other to the left side of the animal. The common oyster and mussel are examples of this class of acephalous mollusca.

The *Encephalous Mollusca*—those with heads—are divided into classes, according to modifications of the locomotive organs. The *Pteropoda* (wing-footed) swim by two wing-like muscular expansions, extended outwards from the sides of the head.

The *Gasteropoda* (stomach-footed) creep by means of a muscular disc, attached to a greater or less extent of the under part of the body.

The *Cephalopoda* (head-footed) have all or parts of the locomotive organs attached to the head, generally in the form of muscular arms or tentaculæ. These classes have numerous genera, including many species.

217. In the next class, the Insect tribe—we arrive at the highest organization of the articulate animals: the organs of locomotion are doubled, and in some instances even more; and instead of trailing on the ground or swimming in the sea, they are provided with jointed and flexible legs and feet; with wings to lift the body into and traverse the air. The power of flight is not given to every insect, nor does any insect obtain it until its form is changed from that in which it commences its existence. All undergo many and remarkable changes before they reach their ultimate form: some remain without any means of progression than the vermicular; others have numerous feet without wings,—as many as eighty pairs in some instances. These are termed *Myriopoda* (ten-thousand feet); centipedes, wood-lice, &c., are examples. The perfect insect has never more than three pairs of articulated legs, with two or more pairs of wings.

Those insects that acquire wings are classed according to certain modifications of these organs of locomotion. Thus, with two wings they are styled:

Diptera (two-winged); such as flies, gnats, &c.
Lepidoptera (scaly-winged); butterflies, moths, &c.
Hymenoptera (membrane-winged); bees, wasps, &c.
Heminoptera (half-winged); bugs, plant-lice, &c.
Neuroptera (nerve-winged); May-flies, dragon-flies, &c.
Orthoptera (straight-winged); crickets, cockroaches, &c.
Coleoptera (sheathed-wings); beetles, &c.

Those insects that are devoid of wings, are termed *Aptera* (wingless).

218. A class of articulate animals, forming a branch as it were of the great family, has been termed *Arachnoidea* (spider-like). They are commonly known under

the name of mites, scorpions, and spiders. These animals are wingless; some terrestrial, and a few aquatic. This family includes some species very low down in the scale of organization; one, the *Demodex*, is a microscopic parasite of the human skin (fig. 26).

Fig. 26.

MAGNIFIED VIEW OF DEMODEX.

219. The Fishes are the proper vertebrated inhabitants of the water. They are organized for living and moving wholly within this element; and from the greater extent of the water over the land, and the prolific nature of this class of animals, they probably exceed in numbers the whole of the other classes of animated nature: the young produced by one cod fish, at a single deposit, being ascertained to be not much less than 4,000,000; while in the common flounder they are not fewer than 150,000. They inhabit the waters at various depths; some near the surface, others near the bottom, and others again through the intermediate depths. The whole class of fishes has been divided into several orders and genera, based upon certain peculiarities, such as bony fishes, spinous and soft-finned fishes. Fishes in general are characterized as cold-blooded, although a certain amount of heat must be present to preserve the fluidity of the blood.

220. The class of vertebrated animals the Reptiles, comprehend the tortoises, lizards, crocodiles, alligators, serpents, frogs, toads, salamanders, &c. They in general inhabit the land, but many species are fitted to remain in the water, although unable, like fishes, to breathe in it. Reptiles are classed as cold-blooded.

221. From Reptiles we ascend to Birds. These animals are warm-blooded, and the greater portion are furnished with organs to enable them to rise above the

surface of the earth, and move in the air. Others are wingless, and unable to fly, but move on the land with great swiftness. Their outward covering is peculiar to them, and consists of a structure well known as feathers. These may be considered as clothing feathers, and those subservient to locomotion. The feathery portion, or barb, grows upon a shaft inserted into the skin, and are thrown off and renewed once, sometimes twice, in the year; this process is called *moulting*. The structure of the feather combines lightness with strength, and in forming the wing affords a large expanse of surface, which being made to strike the air with great force and rapidity, by means of the powerful muscles attached to it, enables the bird to overcome the force of gravity.

The brain of birds is developed to a much greater extent than in any of the preceding classes, and presents in the whole class a great uniformity of structure.

Birds are divided into orders and genera, from peculiarities attending various tribes, either in the formation of the feet, or from their habits. Some have webbed feet, and are fitted for swimming; some with feet partially webbed, with long naked legs, are termed *waders*, or shore-birds. Those that feed exclusively on flesh are termed birds of prey; others, from their affinity to our domestic poultry, are termed *gallinaceous*. From their habits, some are designated *climbers*. The most numerous order of the whole class is the *passerine*, or sparrow tribe. It embraces a vast variety of apparently very different families of birds, nevertheless a great resemblance of structure prevails.

222. The mammalian class of animals is the highest in the scale, and includes man. The lowest order of this class is the *Cetaceous*, or whale tribe. This includes whales, porpoises, and dolphins. Although, to all appearance fishes, they are, from their conformation, and from the mode of rearing their young, strictly mam-

malia. Not being provided with gills, like true fishes, they are compelled to rise to the surface of the water to breathe, but are provided with the means of retaining sufficient air to enable them to remain a considerable time beneath the surface.

223. The *Ruminantia* include a large portion of the mammalians: they form the most important, because the most useful, to man. Their flesh supplies him with food; they yield him milk, tallow, &c.; and are useful as beasts of burden. The name ruminantia, indicates the singular faculty possessed by these animals of masticating their food a second time, it being returned to the mouth after the first deglutition. This faculty depends upon the structure of their stomachs, which are always four in number. These hold a large amount of herbage, the usual food of this class of animals, and hence termed *herbivorous*, and when the animal is at rest the food is returned to the mouth in little pellets, or *cuds*, to be re-chewed.

The camels, deer tribes, goats, sheep, oxen and buffalos, are of this order.

224. The *Pachyderms*, or thick-skinned animals, include the elephant, rhinoceros, hippopotamus, horse, hog, peccaries, and tapirs.

225. In the *Edentata*, or toothless animals, are found the sloth, armadillos, ant-eater, and that singular species belonging to New Holland, the *ornithorinchus paradoxus*, or duck-bill.

226. The *Rodentia*, or gnawing animals, include the wombat, squirrel, rat, marmot, mouse, gerbil, hare, rabbit, beaver, porcupine, argouti, and the cavy, or guinea-pig.

227. The *Marsupiata*, or pouched animals, of which the kangaroo and opossum exemplify the peculiarity of this order, are distinguished by a pouch in which they carry their young from the period they are born alive to the time required to fit them for an independent existence.

228. The *Carnivora*, flesh-devouring animals, compose a large order of mammals. Although described as feeding exclusively on flesh, some are enabled to subsist upon vegetable food, or rather a mixture of the two. This order includes the beasts of prey—lions, tigers, cats, pumas, &c., forming the feline tribe. The canine division includes dogs, foxes, wolves, and hyenas. The seals, otters, and morse, form a minor division of this order, and are termed amphibious, from their aquatic habits. The bat tribes, though mostly, are not all carnivorous, but find their place in this order. Their principal distinction is a membrane, stretched upon elongated fingers, and reaching to the hinder extremities, enabling them to fly.

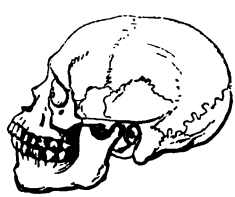
229. The *Quadrumana*, four-handed animals, include the ape and monkey tribes. These animals approach the nearest to man, and are therefore considered as the second order of mammalians, man being the first.

230. *Bimana*, or man, takes his place in the animal kingdom as the first. In his case there is no subdivision into genera—he forms but one genus, and that the only one of its order. Nevertheless there are apparent varieties of race, distinguished somewhat slightly in formation, more decidedly in difference of colour, and with different degrees of development. Of these varieties, three give the greatest apparent distinctive differences, the negro, or black—the Mongolian, or yellow—and the white. Much controversy has existed as to whether man has primarily sprung from one or many distinct sources. At this period of time there is no possibility of determining this question from any positive evidence. There is a negative evidence which, if duly considered, might go some way towards determining the question.

It is now well ascertained and understood, that unfavourable circumstances, such as severity of climate,

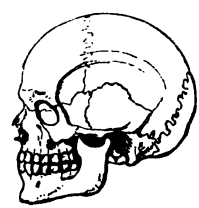
want of sufficient nourishment, with utter neglect of mental culture, deteriorate man to almost an equality with the lower animals. On the other hand, the advance and development of man evidently depend upon the favourable circumstances by which he may be fortunately surrounded. It follows, therefore, that all the diversities of man in his physical formation and cerebral development *may be* the result of the external terres trial circumstances in which he has been placed, and that, therefore, one common origin *may be* all-sufficient for the manifold varieties met with. This circumstance must also be noted, that as the fœtal development of

Fig. 27.



NEGRO.

Fig. 28.



WHITE.

man, as will hereafter be shown, exhibits an analogue of the various stages in which many animals exist in their perfect condition, so does the conformation of the fœtus of the more perfect race of man—the white—at an undeveloped period of its growth, present an analogy with the form that is persistent in the negro,* (fig. 27, 28).

ANIMAL NUTRITION.

231. The process of nutrition in the animal kingdom, though, in some respects greatly similar, is essentially different in many respects to that of the vegetal, inasmuch as

* See Cuvier and Owen.

the latter receives its nutriment solely from the inorganic kingdom—no waste of material occurring in the process—whilst the animal receives its food in the forms of portions of organisms, which, after undergoing certain chemical changes in the animal laboratory, become a composite fluid, answering the purpose of the sap in plants; carrying to all parts of the animal body the materials for adding to its bulk, or sustaining its mature growth, but with this difference, that as in the animal there is constant waste and destruction of its various parts coincident with its renovation, the nutritious fluid in addition carries in its returning stream the effete particles, to be either re-modified for further use, or ejected from the body as useless. Again, only so much of the necessary inorganic elements is imbibed by the vegetal tissue as shall form precisely the required fluid or sap for the nourishment of the plant; whereas, the mass of crude food passed into the interior of the animal has to undergo an elimination or separation of its essential or nutrient portions from the useless—the latter passing off from the body as fæcal matter. From this it will be seen there are two distinct ejectments of material waste, the natures of which will be shown hereafter.

232. In the lowest class of the animal kingdom—the Radiata—the organs of nutrition are simple, the infusoria and hydatid being little more than stomachs, with a common inlet for the food, serving for the outlet of the egesta. Complexity of structure of the organs of nutrition advance with the grade of the animal, but until we arrive at the Vertebrata we do not find any very great complexity of arrangement, a great proportion of those lower tribes consisting of animals whose principal purpose of life appears to be nutrition and reproduction, the instinctive or intelligent structure not being more developed than is sufficient for these pro-

perties, each class forming the appropriate food of some other. In the vertebrata, intelligence becoming more developed, a more elaborate elimination of the crude elements of food is required, and a corresponding complexity of structure and functions of the organs of nutrition obtains, and as these reach their culminating point in man, the consideration of their details will be deferred to the section on human nutrition.

ANIMAL REPRODUCTION.

233. The reproduction of animals is essentially analogous to that of plants. It takes place either by spontaneous fission, by gemmation, or by oviparous generation.

The first of these, the *fissiparous*, is the primary and most simple type, and is the mode in which some of the lowest classes of the radiata are propagated. It is found in the infusoria, the entozoa, in polypi, medusæ, and annulata. In some infusoria the division takes place every twenty-four hours, and in this way in the course of four weeks one animalcule will produce upwards of two hundred and fifty millions of new beings (fig. 29). This mode of reproduction is analogous to that of the lowest plants—the cellulares, fungi and algæ.

Fig. 29.

The next form of reproduction, the *gemmiparous*, is that in which the offspring arise from the parent in the shape of gemmæ or buds, and separating, assume an independent existence (fig. 30). This perfect exemplar of vegetal propagation and growth is found in infusoria, polypi, annulata, and tunicata. These forms of reproduction do not require the distinction of sex, and plants and animals thus circumstanced are termed hermaphrodite.

Fig. 30.

In some low forms of animal life a most remarkable

phenomenon has been observed, to which the term parthogenesis, or virgin procreation, has been given. It is found that the parent animal gives birth to an embryo different to itself; that this embryo lives as an independent animal, and gives birth without fecundation to another and successive series, until at length a progeny is formed bearing the likeness of the original parent. The salpæ among the mollusca, the distoma among the entozoa, and the aphides among insects, present examples of this singular law.

The third form of reproduction, the *oviparous*, has its analogue in vegetation among those plants whose organs of reproduction are of distinct sexes, born upon different flowers. In animals the one bearing the organs corresponding to the pistil of the plant is the female; this contains the ovary or receptacle for the egg. The male contains the fecundating organs answering to the stamens of the plant. This form of generation is met with early in the animal series. Distinct organs are found in some of the infusorials, but in the lower series of the zoological scale, oviparous is mixed up with fissiparous and gemmiferous generation. It is in insects, fishes, reptiles, and birds, that oviparous generation reaches its full development. All insects and fishes are dicœcious, or of distinct sex, and in the latter is found the commencement of the ovary as it exists in the higher classes of vertebrata. In the marsupial tribes the fecundated ovum remains but a short time within the parent and at an early period is transferred to the marsupium, or pouch, where it remains during the remaining term of its fœtal development.

In the mammalia the ovum is invariably fecundated within the ovary, and having undergone various stages of development, from the germinal cell to the complete form of the young animal, it is extruded, and from this circumstance the mammalia are designated *viviparous*,

but for a certain period, of varied duration in the several tribes, it is still dependent upon the parent for sustenance derived and procured from the mammæ or breasts, before it arrives at a stage fitting it for an independent existence. In man this process arrives at its highest point of development.

234. Man, like every other animal and plant, commences his life from a single cell. This cell, formed and existing in the human ovary, is fertilized in like manner as are all other animal cells, and proceeding to the womb it there remains during the period required for its growth and organic formation. At the end of this period it is extruded, and commences its terrestrial life, still dependent however, like all others of the mammalian class, for sustenance derived from the parent.

In this probationary existence, the human embryo during its formative growth, and while gradually progressing towards its ultimate perfection, successively but temporarily assumes many of those forms which are retained by some of the lower animals as their permanent condition of existence. In its first cell-like form, it is almost identical with the simplest animalcule—the monad. The first appearance of the heart is a mere pulsating vessel without any division into cavities, such as is found a sufficient instrument of circulation in the perfect insect. A further dilatation of this tube converts it into the single heart of the fish. As it advances a second cavity is added, and it becomes a counterpart of the adult reptile.

The lungs also are developed in a form analogous to the air-bladder of fishes, and which is discarded for the mammalian lung as development proceeds, so that "as the organism of the human fœtus cannot be supposed to be formed with the idea of providing for aquatic respiration, we can no longer doubt that the whole series of phenomena which takes place during the

development of the fœtus do not result from any special interposition of divine agency for each individual occasion, but from the *action of fixed and general laws.*" (Solly, on the Brain.)

INTELLIGENT AND INTELLECTUAL MATTER.

235. The peculiar structure which more particularly distinguishes the animal from the plant, and in which resides the property, power, or action called instinct or intelligence, exists in the lowest and simple grades in a corresponding simplicity of form, and as complexity of structural arrangement with diversity of functions rise in importance in the animal scale, so does this *intelligent structure*, or the *nervous system* as it is termed, become correspondingly increased in amount of matter, complexity of arrangement, and concentration of form.

This peculiar substance is designated *neurine*, and of this there are two distinct kinds, differing both in consistence and colour, one being grey or ash-coloured, soft and pulpy—the other of a pearly white, and fibrous texture. The ash-coloured or cineritious portion consists of semitransparent globules of unequal size contained in the meshes of a network of delicate tissue, and containing a greyish fluid. The white or fibrous portion consists also of globules containing a milk-like fluid, but placed relatively to each other in a cylindrical form.

The chemical analysis of neurine gives for its component elements, albumen, fatty matter, phosphorus, sulphur, osmazome, and water.

236. In some of the lower forms of animal life, this nervous matter is dispersed in the substance of the animal, and so unconnected that it would be difficult to demonstrate it as a system, but in the ascaris, one

of the entozoa, the nervous matter is found in its simplest form of arrangment, when so far concentrated as to form a distinct system. Two white cords, rather thicker in the middle of the body than at the extremities, sending to the right and left filaments so fine they escape the eye unless assisted by a lens, constitute the nervous system of this animal (fig. 31). In the molluscous tribe the nervous system is still rudimental, and scattered in an irregular manner throughout the substance of the animal. The powers of intelligence or instinct are limited to the development of vegetative life, and only just so much as is required for this purpose seems to be accorded.

Fig. 31.

A marked advance is perceived in the nervous system of the annulata. A central chain of small knots of neurine (or ganglions) extend from one end of the body to the other, connected by the white fibrous substance, forming what are termed commissures, or conjunctive cords. The chain commences by a symmetrical bilobed ganglion, almost meriting the name of "brain;" from the ganglia are sent off filaments of nervous matter to the various organs of the animal. In this are seen all the component parts of nervous structure and arrangement, central ganglia, commissures and nerves. In the medicinal leech this arrangement is beautifully exemplified (fig. 32). In the crustacea a greater concentration of nervous arrangement takes place. The longitudinal cords of the lower tribes approach each other more closely, and the head-ganglia become increased in size. In the insect tribes the concentration of the superior ganglia in the region of the head become entitled to the appellation of a brain.

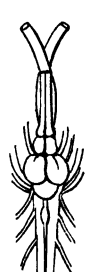
Fig. 32.

LEECH.

237. In the next advance of nervous development in

the vertebrata a special provision is made for the protection of the structure, by its being enclosed in a bony case, and from the lowest order of this class—the fishes,—to the highest—the mammalia, a constant relative advance is perceived between complexity of structure and organic function with intelligence, until the series becomes perfected in man. "The wider our survey of living nature extends—the greater the number of facts in the history of animals with which we become acquainted, the more do the points of correspondence between the different species increase, and the clearer becomes our conception of the unity of the general plan which pervades their organization." (Owen's Lectures.) The central chain of ganglia become so closely united that all appearance of a chain is lost, and a nearly uniform cord supplies its place, which, from the relative situation it holds, is called the *spinal cord.* The superior extremity becomes expanded into a series of ganglia, forming a large mass of neurine, and this constitutes the *brain,* properly so called, of the vertebrate animals. The degrees of concentration which take place in the various ganglia constituting this mass are conspicuous upon comparing the brains of the

Fig. 33. FISH.

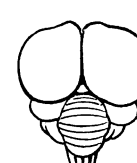


COD.

Fig. 34. REPTILE.

TURTLE.

Fig. 35. BIRD.



BUZZARD.

Fig. 36.
MAMMALIA.

RABBIT.

Fig. 37.
MAN.

In the fish and reptile the head-ganglia are separate and occupy more space. In birds, with a greater advance in intellectual powers over those of fish and reptiles, is perceived a greater development of the neurine mass composing the superior portion of the brain. The different ganglia are placed in closer juxtaposition, and the upper or cerebral lobes termed hemispheres are so much increased in size as to overlap and cover the others. The spinal cord becomes thicker than in fishes.

In the mammalia, although there is no sudden transition from one form of brain to another, the advance in the relative quantity of matter, and the concentrated disposition of its parts is most striking. The hemispheres, except in the lowest members of the class, begin to put on a convoluted appearance—by this is meant a folding together of the superior portion of the cerebral mass, so that it is made to occupy a much smaller space than it otherwise would do. This may be exemplified by the fact of a handkerchief occupying much less space when folded or crumpled up, than when spread out. In the rat, mouse, marmot, beaver, and rabbit the hemispheres are as smooth as in birds; in the sheep, dog, elephant, and horse, the brain is convoluted as in man.

238. In man and all vertebrate animals the spinal cord is formed previously to brain: at first it consists of two cords, which afterwards unite, and at the superior extremity they become gradually developed into those distinct masses forming the component ganglia of the brain. Of these masses arising from the columns of the spinal cord, a greater and a less conglomeration are respectively termed the *cerebrum* or great brain, occupying the fore and upper part of the head, and the *cerebellum*, or little brain, occupying the under and back part of the head. The cerebrum is formed externally by convoluted masses of cineritious neurine, beneath which is found the white and fibrous structure, and the cerebrum divided above into two distinct lobes or hemispheres, becomes united below by a mass of white fibrous neurine.

The cerebellum is also composed of the two kinds of neurine, but differently arranged.

Fig. 38.

BRAIN AND SPINAL CORD.

239. The great difference and distinction between the brain of man and the brains of all other mammalia, lie in the greater proportional quantities of matter composing the cerebrum relatively to the size of the body, and the greater relative size of this portion of the brain to the others. Also, that the intelligent structure of the lower animals is made subservient to the mere vegetative functions of the body and its mode of existence; whereas in man, the body serves as the adjunct, and is subordinate to the intellectual structure.

The MAN *therefore may be said to consist essentially of the mass composing the brains and spinal cord.* It is the actions of the component parts of this mass of matter that constitute all those varied sensations, feelings, passions, attributes,

and properties that make up in the aggregate, what is understood by the term, *the human mind.*

240. All the organs in the body, the functions of which are purely vegetative and act independently of the will, such as the organs of nutrition and reproduction, are supplied with a nervous system, which although communicating with the brain and spinal cord is entirely distinct from those functions which are recognized as intellectual. The arrangement of this system consists of scattered ganglia, a double chain of which are placed on each side of the spine, with nerves communicating with each ganglion, and ramifying to all the above-mentioned organs, and indeed to every portion of the body that has an action independent of the will.

The nature of the special functions of this separate ganglionic system is involved in some obscurity, and great diversity of opinions has obtained among physiologists concerning it; but the fact of its being exclusively distributed to the mere vegetative organs, and the structure of the ganglia, (cineritious neurine,) would seem to indicate a system similar to the nervous systems of the invertebrata, which in them are sufficient for the limited functions of their existence, and which in the highest orders preside over the same or parallel functions, but communicating with the purely intellectual structure, is greatly influenced though not commanded by it.

Fig. 39.

BONY CASE OF BRAIN AND SPINAL CORD. THE SKULL AND VERTEBRAL COLUMN.

241. The mass of matter which has been described as the *intelligent structure* of man—the brain and spinal marrow—is protected from external injury

by being enveloped, firstly, in three membranous coverings, and secondly, enclosed in a strong bony case—the skull and vertebral column. The membranous coverings are of varied thickness and strength, the bony case consists of a jointed column of great strength combined with considerable mobility. The upper end is expanded into a large cavity—the skull—and contains the cerebrum and cerebellum, the spinal cord occupying the cavity of the column.

242. For the purpose of direct communication with the external world, organs of special sensation are provided; these are, the olfactory for smell, the optic for vision, the auditory for hearing; and to these must be added, though not an organ of sensation, the lingual for speech, as forming one of the most important of the media for communication with the world. The media of communication between these external organs and the internal sensating ganglia are *the nerves*—tubular neurine filaments passing from the one to the other.

243. For *locomotion* special organs are provided, the *muscles* affixed to a jointed bony framework.

244. For the reception of aliment and its conversion into the nourishing fluid which in animals is called *blood*, there is a most complex and elaborate apparatus, consisting of a set of organs to tear, mix, dissolve, and eliminate; and these various processes are termed in the whole *digestion*, and the apparatus the digestive organs—the perfected series of the organs of nutrition in plants and animals.

245. To carry this nutrient fluid to all and every part of the body there is a system of elastic tubes, called arteries, through which the blood is forced by means of a hollow muscle, *the heart*,—a species of forcing pump. Another system of tubes—the veins—carry back the unused and refuse portions, to be reconstituted on the way, by the constant addition of newly-

formed blood, by modes of purification, or by ejection from the body.

246. In conjunction and combination with this process is the production of animal heat: this is effected by a constant combustion of carbon with oxygen, and the unition of the two elements is effected principally in the lungs—the animal furnace for this purpose—but also over all parts of the body.

247. As a prehensile organ an upper extremity is added to the body, to which is prefixed *the hand.* The superiority of this organ over all those proper to the lower grades is as great and manifest as is that of the human over all other brains.

248. The bony framework forming the scaffolding and support of the soft structures of the body is termed the *Skeleton*, and consists of a great number of jointed bones placed so as to form levers and fulcra for the actions of the various muscles. The structure of bone is a membranous network, the meshes of which are filled up by calcareous matter. The central portion of this framework is formed by the vertebral column—a series of strong bony rings of irregular shape, the uppermost of which is expanded into the skull, and the lower ones into a broad base for the attachment of the bones of the lower limbs. This base is called the pelvis, it having somewhat the form of a basin. The lower extremities are formed by the jointed union of several long cylindrical bones supported by an expansion of small ones forming the feet. From the upper portion of the vertebral column several pairs of elliptic-shaped bones are thrown out, which, meeting in front, form a cone-shaped cavity called the thorax or chest. Placed laterally upon the thorax are the upper extremities, formed like the lower by similar long bones ending in the hand and fingers—a modified analogue of the feet and toes.

The ends of the bones forming joints are covered by a smooth lubricated substance called cartilage, and are

Fig. 40.—SKELETON.

bound and kept in their places by tough membranes termed *ligatures*.

249. The muscles, which by their peculiar action move these bones, are made up of fleshy fibres endowed with the power or property of contractility, so that a muscle at rest, by contracting its length, causes, by the shortening, the points of the bones to which its extremities are attached to approach each other. As there are many pairs of muscles attached to each bone to be moved, and antagonistic to each other, their combined actions make up a large sum of force and variety of direction.

Fig. 41.—MUSCLE AT REST.

Fig. 42.—MUSCLE IN ACTION.

To obviate the inconvenience which would arise from a large bulk of fleshy muscle attached to each bone, a tendon or sinew is added to some muscles of a tough and inelastic structure, acting in the manner of a rope, and in some instances passing over a kind of pulley, thereby increasing the power of traction, and modifying the straight direction of the muscular force.

The ultimate fibres or fibrillæ of muscles are microscopically minute, and form into fasciculi, or little bundles, and these again into larger ones, and thus the aggregate of the muscle is made up. In these fibrillæ arise the extremities of the nerves, which in like manner unite and form a common trunk usually passing into the spinal cord and blending with its substance into the brain. Along this nerve is conveyed the will of the brain to the muscle, which contracts in a stronger or weaker degree according to the dictates of that will. Those muscles so circumstanced and obeying those

dictates are termed *Voluntary;* but a large number concerned in the actions that are purely of a vegetative or nutrient character are not under its control, but act constantly and in opposition to the will, and are hence termed *Involutary* muscles.

ORGANS OF NUTRITION IN MAN.

250. In plants, food is required for nutriment only; in the animal body it is required for two distinct purposes: one to supply the materials for growth, and the waste caused by the constant action and decay of its various parts requiring as constant a renewal; the other to supply the materials required for combustion, in order that the heat of the body may be kept up to a constant and certain standard. For these purposes numerous organs are associated, and form in the aggregate a very complex apparatus; those destined for nutrition being also subservient and conjoined to those productive of heat.

The first group provide for the reception, digestion, and distribution of the aliment, with the means of ejecting the refuse and unused portion. The second, for the combustion of the materials set apart from the aliment to produce heat.

For the first purpose, the associated nutritive organs consist of the mouth, provided with teeth, and secreting glands to pour forth a fluid called *saliva.* Here the crude food is ground and mixed with the saliva, and forming a moist pulpy mass is passed through a long muscular tube — the *œsophagus,* or gullet — into the stomach. This first act of digestion is termed *mastication.* In mastication the tongue (an organ having many offices to perform) takes part by assisting the conveyance of the food to the entrance of the gullet.

251. The *Tongue* is an oval muscular body attached

to the back part of the mouth, and having a very free motion. Upon its enveloping membrane is dispersed the extremities of the nerve the special function of which is *taste*. As the olfactory perceives and conveys the odorous impressions of substances, so does the gustatory nerve convey to the brain the impression given to it by its contact with sapid substances, and produces the sensation called *taste*. For the due performance of this sense moisture is necessary, and saliva is poured forth from secreting glands placed around the tongue for this purpose.

252. The *Stomach*, into which the food is passed, is an irregularly shaped membranous and muscular bag, lined with a secreting membrane exuding a peculiar fluid called the *gastric juice*, and to the action of this fluid the alimentary mass is submitted. This fluid is not present in the stomach while empty; its secretion is induced by the presence of food, and the amount of secretion is regulated not by the quantity of food swallowed, but by the nutritive requirements of the system, so that if too large a quantity be swallowed, only a certain portion is acted upon by the gastric solvent, and the remaining portion must either remain in the stomach until a fresh supply is required, or pass undigested into the intestines,—in either case a source of irritation and disease to the individual. The digestive change which the food undergoes in the stomach by reason of the solvent action of the gastric juice is a purely chemical process, and to a great extent independent of vital action. A peculiar organic compound, to which the name of *pepsine* has been given, forms the principal constituent of the gastric juice, and it is to the property that pepsine possesses of changing the heterogeneous mass of food into a uniform pulpy substance, which has received the name of *chyme*, that gastric digestion depends. The peristaltic muscular

action of the stomach subjects the mass of food during *chymification* to a kind of churning, and each portion as it becomes chyme, passes from the stomach through its distal orifice, the pyloric, into the continuing intestine called the *duodenum*. Here the chyme meets with two secreted fluids, and mixing with them the chyme then becomes *chyle*.

253. These fluids are the products of two glands, one called the Liver, secreting the bile; the other, the Pancreas, secreting the pancreatic juice.

The *Liver* is a large solid glandular mass, of a dusky red colour. Its office is to secrete, in great abundance, a peculiar fluid—the bile; and which is deposited, as soon as it is secreted, in a receptacle at the under part —the gall-bladder: from this a duct issues into the duodenum, and through it the bile passes to be mixed with the chyme.

Bile consists of 48 parts of carbon, 42 of hydrogen, 13 of oxygen, and 10 of nitrogen.

254. The *Pancreas* is a long flat gland, lying between the stomach and spine; secreting a fluid—the pancreatic juice—very similar in appearance and quality to the saliva.

255. The chyle, thus formed, is a milky opaque fluid containing minute globules of fatty matter, albumen, saline substances, and water. The relative proportions in 100 parts are as follow: fatty matter, 3 per cent.; albumen and fibrine, $6\frac{1}{2}$ per cent.; salines, $\frac{1}{2}$ per cent.; water, $90\frac{1}{2}$ per cent.

256. The chyle is absorbed by the open mouths of minute vessels, called *Lacteals* (from their white milky appearance), thickly studded over the inner surface of the duodenum and continuing intestine. These vessels, when full, have a knotted appearance from the presence of small valves which prevent the fluid from regurgitation. These vessels, ramifying upon the intestine,

unite and form a large duct, termed the *Receptacle of the chyle*, and which extends from the loins to the upper part of the thorax; where, making a turn in descent, it enters one of the large veins, and discharges its contents into the stream of blood *returning* to the heart.

257. In addition to the chyle in the receptacle, derived directly from the digestion of fresh food, there is always mixed with it a fluid called *Lymph*, brought by another set of absorbent vessels — the Lymphatics (similar in structure to the lacteals) from every part of the soft tissues composing the body. Lymph is different in composition to chyle in being comparatively transparent or opalescent, and in being destitute of fatty globules. It is the unused elementary portion of the various tissues returned into the circulation for further use. In the case of starvation, life continues so long as the absorbents can procure from the tissues their elementary nutrient particles, and carry them into the circulation: when they are exhausted and the supply ceases—death ensues. Chyle, therefore, is composed of fresh-digested matter and lymph.

258. In order to render the three-fold mixture of chyle, lymph, and returning venous blood fit for its ultimate form of perfect nourishing fluid—blood—it has to be exposed to the influence and action of the atmosphere, in order to obtain from it an addition of oxygen: firstly, to oxygenate the imperfect blood, thereby imparting to it the bright vermilion colour of arterial blood; and secondly, to combine the oxygen with the surplus carbon, and by the combustion thus produced to generate the required amount of animal heat.

These atmospheric changes are effected by means of the *Lungs*—two soft spongy bodies occupying the greater part of the cavity of the thorax, and in their shape corresponding with it. They are composed of minute

air-cells with free communication; these agglomerate into lobes,—the lobes into right and left lung, and both are conjoined by a large tube, called the *trachea*, or windpipe, which opens at the back part of the mouth, and is defended at its entrance, from foreign bodies passing into it, by a movable valve or trap—the *epiglottis*. The windpipe is the common root of smaller tubular branches, which become less in diameter as the ramifications extend through the substances of the lungs, until their minute extremities end in the pulmonary air-cells.

The vessels carrying the venous, or imperfect blood, to be aërated, in like manner minutely ramify through the membranous partitions of the pulmonary structure; and their thin walls being permeable to the influence of the atmosphere, the change is thence effected; and the pure blood taken up by the terminations of other vessels is by them conveyed back to the heart to be distributed to the body for its nourishment.

259. The organs for conveyance and distribution consist of the *heart*, the muscular forcing power; the *arteries*, the vessels proceeding from it; and the *veins*, the vessels returning to it. Between the final extremities of the arteries and the commencement of the veins, a third description of blood-vessels exists; so fine and minute in their structure and diameter, as to cause them to be designated *capillary vessels*. It is while passing through these latter vessels that every change in the blood takes place,—whether for the deposition of new particles to the decaying structures; the elimination of the various accessory glandular secretions; or the withdrawal of effete particles to be ejected from the system.

The *Heart* is a hollow muscle divided into four distinct cavities, and enclosed in a membranous bag, called the *pericardium*. Two of its cavities, much larger than the others, are termed *ventricles*, and distinguished

into right and left. The two others are small appendages to the larger ones; and from their similitude to a dog's ear, are termed *auricles*. The muscular fibres are so disposed, that when the ventricles are in action the auricles are passive, and *vice versâ*.

At the entrances of each of the cavities, valves are so placed that the blood is prevented from regurgitating.

The *Arteries* are tubes formed of coats composed of muscular and fibrous-elastic tissues, with a covering and lining of smooth cellular tissue. In proximity to the heart they are thick and powerful; but in proportion to their recession from it, their walls become thinner. The main trunk springs from the left side of the heart.

The *Veins* are flexible tubes much thinner and less elastic than the arteries; and are provided, in addition, with internal valves placed at certain distances along their course to prevent the reflux of the stream of blood in returning to the heart.

The *Capillaries*, as their name implies, are hair-like in their fineness, but possess a high degree of elasticity.

260. The blood is brought by the veins to the right auricle of the heart, from all and every part of the body; the auricle thus filled is stimulated to act, and, contracting, forces its contents into the right ventricle; the contraction of this ventricle sends the impure and deteriorated venous blood loaded with carbon to the lungs, where being renovated or sanguinified by the air and its carbon partly consumed by its combustion with oxygen—thereby producing heat—it is carried by the returning vessels to the left auricle, from thence into the left ventricle, which being stronger and more powerful in its action, forces the blood into the arteries. The peculiar muscular and elastic structure of the arterial vessels enables them to assist the heart in the transmission of the blood; the force and impulse of the heart dilate the elastic arterial tube. The

contracting action of the tube propels the blood in its onward course upon the intermission of the heart-stroke.

261. The pure and living blood thus conveyed, although homogeneous in its appearance, may be seen to consist of a transparent nearly colourless fluid, in which red corpuscles freely suspended give the whole its red hue, and which with other white corpuscles are carried along by the current. If the blood be drawn from the body, and allowed to remain at rest, a spontaneous separation takes place: the red corpuscles agglomerating and forming a compact mass surrounded by the clear fluid or serum. The clot is composed of the red and white corpuscles, while the serum consists of albumen and saline matters in solution, and water. The red corpuscles, commonly but erroneously called globules, are flattened discs (fig. 43.), and owe their bright colour to a peculiar substance which envelopes them, called hematosine. While circulating in the arteries the corpuscles appear of a bright vermilion, but in the veins they lose their bright hue and appear of a dark purple, while in the capillaries they become isolated and lose the appearance of redness which they possess in aggregation. The blood discs may be regarded as cells, similar to those which constitute the simplest plants, and like them, having an independent and creative life of their own, possessing the power of reproducing themselves. The white corpuscles found also in plentiful association with the red, appear to be cells analogous to those formed in the circulating vessels of the invertebrate animals. The principal office of the red discs would seem to be, to convey the oxygen they acquire in the lungs to all parts of the body, for the purpose of generating heat. The white corpuscular cells appear to possess the creative and reparative power.

Fig. 43.

262. In the blood is contained all that forms the solid parts of the body, and from it is eliminated and secreted the various fluids that perform their important offices in the animal economy. Wherever a free membranous surface exists in contact with the air, a lubricating and protective fluid termed mucus is poured out.

In all the closed cavities a watery fluid is constantly present, existing perhaps rather in the form of a vapoury exhalation than as a dense fluid, and secreted by the lining membrane. In the various movable joints a lubricating fluid, called *synovia*, protects the cartilages from the effects of friction.

263. In many, or indeed in all parts of the body, peculiar structures are found whose office it is to elaborate from the blood, as it passes through them, some special fluid for some specific functional purpose. These structures are called *glands*, and are placed in such situations that the fluid they secrete can be readily applied to the purpose required ;—for example, a small gland placed over the eye secretes the tears, for the lubrication and preservation of the transparent cornea: the salivary glands around the mouth pour forth their fluid at the bidding of the slightest stimulus: the liver, never rests from supplying bile: the whole internal surface of the intestines is studded with minute glands that furnish in conjunction with its lining membrane the necessary mucus: from the cutaneous covering of the body a moisture in the form of *perspiration*, either sensible when copious, or insensible as an exhalation, preserves the balance of the temperature of the body; but wherever these fluids are present, and whatever their composition may be, they are all, as well as the solid structures, furnished by and elaborated from the blood. How these wonderful transmutations are perfected we know not: they appear to take place during the transit of the blood through the capillary vessels.

264. That portion of the chyle left in the duodenum, (par. 256, 257,) unabsorbed by the lacteals, passes onward to the next intestine, and so on in succession until it reaches the anal aperture. During this transit the mass is successively acted upon by the lymphatics of the intestines, and any remaining nutritious particles are taken up and conveyed to the receptacle of the chyle, until, deprived of all nutrient properties, it is expelled from the body a useless fœtid mass.

265. Another excretion takes place from the mass of circulating blood, by which all the effete matters, the retention of which would be not only useless but injurious to the body, are removed. To effect this purpose, the whole mass of blood is made to pass through two glandular bodies called *the kidneys*. Any superfluous quantity of water contained in the blood is here separated, together with the products resulting from the waste of the solid tissues, as well as those constituents that have not been converted into organized structure.

The unfitness of these compounds to be retained within the system is partly proved by the crystalline forms in which they present themselves after elimination, such forms being incompatible with organizable properties.

The most important of these excreted compounds is that which is named *Urea*. The ultimate elements of urea are carbon, hydrogen, oxygen, and a large proportion of nitrogen. This substance is held in perfect solution in the water of the urine, and frequently combined with the salts of soda, potash, and ammonia. The great purpose therefore of the urinary excretion is to carry off those products of the azotized tissues which can neither be set free in the form of carbonic acid in the lungs, nor made use of through the agency of the liver.

The excretion of urine takes place slowly, drop by drop, in the substance of the kidneys, and deposited in a

membranous bag—the bladder—until a certain quantity accumulates, which is ejected.

266. An organ, the office of which appears to be supplemental to digestion—the spleen—is a soft vascular body of a dark purple colour, placed between the stomach and left kidney. From its great distensibility it appears to be a diverticulum, or reservoir for the blood, and in this way to act as a safety valve to the venous circulation of the liver when from any cause obstruction is occasioned.

267. The whole body is outwardly covered by a thick strong membrane—*the Skin*—and which consists of three distinct layers; the one next the surface of the body is termed the "true skin," and is continued into the internal cavities of the body. Over the whole surface of this layer are small papillæ, or nipple-like eminences, in which are developed the nervous extremities constituting the sense of *touch*, but at the tips of the fingers this sense is more particularly elaborated, and must be considered as its special organ.

The next layer consists of a substance of a pigmentous character giving its peculiar colour to the individual: in the negro it is black; in the Asiatic, brown; and in the European it is almost colourless. It covers every part of the subjacent layer, excepting below the nails, where it is absent.

The outermost layer—the cuticle, or scarf-skin—is a thin transparent insensible membrane, which covers the other layers. It is much thicker on those parts of the body subject to friction; as the palms of the hands, soles of the feet, &c. This layer gives origin at the ends of the fingers and toes to the horny substances called *nails*, and in various parts of the body to the horny structure called *hair*, which, rising from roots below the true skin, grows to various lengths either as a protection or ornament.

HUMAN NUTRITION.

268. The substances composing the natural food of man may be divided into two classes—nitrogenized, and non-nitrogenized. The first class consists of those substances that contain a large amount of nitrogen, and hence capable of being converted into blood; the second, of those substances destitute of nitrogen, incapable therefore of being converted into organized tissue, but necessary for the supply of elements of combustion, serving to support the process of respiration, and thereby the production of animal heat.

Among the first class of substances destined to afford the pabulum for conversion into vitalized tissue are:—

Vegetable albumen.	Animal flesh.
Vegetable fibrine.	Animal blood.
Caseine.	Osmazome.

Vegetable albumen and fibrine have already been described; and it will only be necessary to add that they are identical in composition with animal albumen and fibrine, found in the flesh and blood of animals.

Caseine is a product of certain vegetables, chiefly the leguminous seeds: it is also the chief constituent of milk, and is the substance that supplies all the elements of nutrition to the young of the mammalia.

Animal flesh and blood contain all the nutrient organic materials required. Osmazome is a peculiar substance obtained from the fibres of the muscles or flesh.

The substances supplying the elements for combustion are:—

Fat, Starch, Gum, Sugar, Wine, Beer, Spirits.

These substances contain a large proportion of carbon in their composition, hence their usefulness and neces-

sity, as food to furnish carbon to be burnt with the oxygen of the atmosphere, forming in fact the fuel for the animal furnace, the lungs.

269. Upon an attentive consideration of the circumstances detailed relative to the formation, growth, and nutrition of the animal body, it will be seen that the food of man should consist of those substances that contain all those elements required by the various tissues for their growth and renovation; for if any element be wanting in the food, such as carbon or nitrogen, the body is incapable of producing them from such food by any chemical or other power of its own: for example, membrane, muscular fibre, hair, &c., can only be formed with a certain amount of nitrogen; all food therefore, destitute of this element, is incapable of being converted into their tissues.

ORGANS OF EXTERNAL SENSATION.

270. *Sensation* is the action and consciousness of a particular portion of the brain, arising from the impression made upon the particular external organ of sensation, as the nose, eye, ear, &c., and conveyed to the sensating portion of the brain by the special nerve for that purpose. These sensating organs mutually assist each other in their perceptions: for example, the eye would perceive all objects as a flat surface, were it not that the sense of touch has by experience informed it that it is not so; without the eye, the sense of touch would give no notion of the colour, shape, and position of objects.

271. The first in order of position of these special organs is the Olfactory, the external seat of which, is in the Nose. Spread over a considerable surface of supporting bone forming the interior of the nose, is a

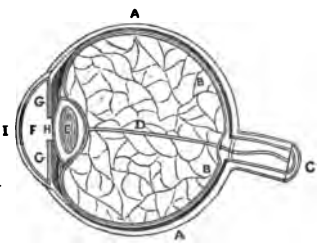
nervous membrane, the peculiar property of which, is to be affected by the odorous qualities of all substances. The external sensation thus produced is conveyed along the proper olfactory nerves to the cerebrum, where they are lost in the substance of two ganglia, in which it is believed the action and consciousness of smell reside.

272. The next in order of position—the Eye—is one of much complexity of structure, being, in fact, an optical instrument of great perfection. Vision is effected by the image of an object being impressed upon a sensative expansion of the optic nerve, called the retina. This impression is conveyed by the medium of light, and by its agency the form, size, colour, position, &c., of the object impressed upon the retina is effected. The impression thus produced is then conveyed along the optic nerve to the optic ganglia, situated at the junction of the spinal cord with the brain, the proper sensating ganglia of the sense of sight.

The optical mechanism by which the rays of light impress the retina with the image of the object seen, is as follows: a series of lenses are so disposed, that light is allowed to pass them by an aperture—the *pupil*—the size of which can be regulated by a circular contracting membrane—the *iris*. The form of the eye is that of a globe, within the back of which is spread the retina; resting upon a layer of black pigment next to the retina, and occupying the greater portion of the globe, is a transparent body, called the *vitreous humour*, performing the part of a lens: before this is placed a much smaller one, the *crystalline lens*, and the space between this lens and the anterior part of the globe is filled with a transparent fluid, called the *aqueous humour*. It is in this part that the circular contracting membrane, the iris, is situated, and this part of the eyeball is transparent and more prominent

than the general form of the globe of the eye. This transparent portion is termed the *lucid cornea*, and the rest of the globe, formed of a tough opaque structure is called the *sclerotic coat*. Into this coat are inserted several muscles, which move the eye in a variety of directions, and adjust it for correct vision; the whole is placed in a deep bony cavity—the orbit—at the fore part of the skull, over which a cutaneous and muscular veil, termed the eyelids, protect the eye from injury (fig. 44).

Fig. 44.



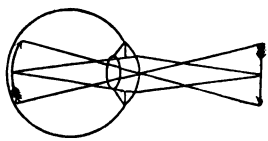
A SECTION OF THE EYE.

A. The sclerotic or outer coat.
B. The retina—expansion of the optic nerve C.
D. The vitreous humour.
E. The crystalline lens.
F. The aqueous humour.
G. The iris—forming the pupil H.
I. The lucid cornea.

The shape and capacity of the eyeball is most wonderfully altered by the actions of the muscles, order to adapt the instrument to the diversity of circumstances under which it receives the visual impressions. Objects placed near or distant are viewed with the same distinctness of vision, that is, within the limits of vision in either case. There being two of these organs, a motive adjustment is also necessary to render what would otherwise be a double sensation, a single one. The rays of light passing from a given object through the front part of the lucid cornea are refracted by its convex surface, and passing through the pupil are made to converge slightly: on their passage through the crystalline lens, they are brought still more closely together; the refracting influence of the vitreous humour increasing this convergence, they are made to meet in a focus on

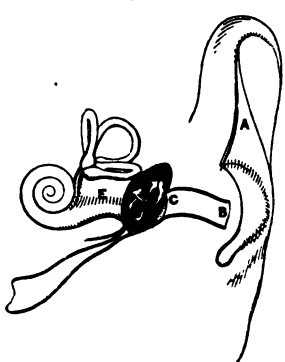
the retina. In this manner a complete inverted image is formed, as will be seen in the diagram (fig. 45). How this inverted image becomes a correct sensation in the optic ganglia we have no means of knowing; we are only cognizant that such is the fact.

Fig. 45.



273. *Hearing* is the sensation produced by sound upon the appropriate organ—the Ear. Sound is the consequence of a substance being made to vibrate, and this vibration is communicated to and prolonged by the surrounding atmosphere. The atmospheric undulations thus produced, reach the auditory organ; and the peculiar character of the sound is then impressed upon the sensitive expansion of the nerve of hearing, and by it conveyed to the brain.

Fig. 46.



THE EAR.

The external auditory apparatus by means of which these sonorous vibrations are brought into contact with the auditory nerve, consists of three distinct parts, — the external ear; a middle portion, the cavity of the *tympanum* or drum; and the internal, or true auditory cavity. The external ear, (fig. 46 A.), situated at the side of the head, is an irregularly-shaped protuberance, semi-cartilaginous in its structure, and adapted to receive and concentrate the vibrations of the

air. From this an opening leads to a short tube (B) communicating with the tympanic cavity, across which is stretched a membrane (C)—the *tympanum* or drum of the ear,—thus separating the external opening from the cavity. The tympanic apparatus interposed between the external ear and the true auditory cavity, consists of a chain of bones (D) stretching across the cavity, from the "drum" to the entrance of the true auditory cavity. These bones are articulated together; moved by minute muscles; and have received names, not from their functions, but from their supposed resemblance to certain objects. The first one—attached to the drum—is called the hammer; the second, the anvil; the third, the round-bone—the smallest in the body, being less than a grain of mustard seed; the fourth, the stirrup. This last completes the chain, and is placed over the true auditory cavity (E). This third cavity, called the labyrinth, from its sinuosities and windings, consists of several bony canals, lined with a membrane upon which the auditory nerve is expanded. The cavities of the tympanum and labyrinth are filled with a clear transparent fluid; and the whole of the internal organ is lodged in an excavation of the solid bone of the skull. A passage or tube communicates with the back part of the mouth, preserving an equilibrium between the air on each side of the tympanum.

The sonorous vibrations of the air, concentrated by the external ear, strike upon the drum, and communicate their vibratory impulse to the fluid in its cavity and to the auricular bones: the action of these bones prolong the effect of the vibrations, and pass them to the fluid in the cavity of the labyrinth; here the auditorial impression is made upon the auditory nerve, and by it conveyed to the brain, where the particular character of the sound is sensated.

HUMAN ORGAN OF VOICE.

274. The organ of Voice, though not exclusively peculiar to man, is one that, guided and controlled by the human will and intelligence, assists in rendering him the superior of all other animals. It is so placed that the passage of the air in respiration shall produce the various required effects upon its organization. The upper portion of the windpipe, which forms the vocal organ, is called the *Larynx*, and is formed by cartilages —ligaments by which they are connected—and muscles by which they are moved.

It should first be understood that vocal sounds, and speech or articulate language, are distinct and different: vocal sounds being produced by the special organ, and speech being modified sounds effected for the most part in the oral cavity. The principal cartilage is that which forms the projection in the front of the throat, commonly called *Adam's apple* (fig. 47 A), and constituting the uppermost portion of the windpipe. The upper orifice, the *glottis* (B), is closed by a movable cartilage (C), the *epiglottis*, stretched across the cavity; and attached to the angles of the principal cartilage are two ligamentous bands, designated *the vocal chords* (D D). The capacity of the tube is modified by various muscles; and the tension and relaxation of the vocal chords are also effected by muscular action. The opening of the larynx—dependent upon the action of the epiglottis, is also under the command of appropriate muscles.

Fig. 47.

ORGAN OF VOICE.

The passage of the air in expiration being controlled by the will, acting on the respiratory muscles, vibrates the vocal chords and epiglottis; and produces those sounds recognized as musical or harmonious, when emitted in a certain rhythmical order. The arrangement of the parts of this organ, and the effect produced, are essentially like those of the clarionet or accordeon; the reed in the one, and the metallic vibrators in the other, performing the functions of the vocal chords.

Vocal sounds in passing through the mouth are modified by the actions of the tongue and lips; and those sounds are produced that properly form speech or articulate language.

CEREBRAL ACTIONS, OR HUMAN INTELLECTUALITY.

275. The actions of the Brain, or *attributes of the mind*, as they are commonly and usually termed, which place man at the head of the animal kingdom, enabling him to subjugate it to his rule, are recognized as Perception, Memory, Will, and Thought; together with the Passions. Several of these attributes and passions are possessed by the lower grades: perception, memory, and will exist in animals, but with them are passive, and beyond this passivity of mental action they never advance. In man, these actions from passive in his early existence become active,—that is, can be excited to act with more or less intensity at any time, at the will of the individual.

The perceptive faculties, Smell, Vision, Hearing, Taste, and Touch, have already been described, as being the results of central ganglionic sensation, communicated by external organs. These faculties, though at first feeble and vague cerebral actions excited in the infant brain, become associated with the first efforts of memory. They however, for a time, remain passive, for as yet the will is an unborn action,—that is, upon the first recurrences of

perception, the memory only recognizes the objects upon each occasion of their being presented, but as the memory becomes exercised and conjoined with the will, the object can be recalled without its actual presence: this is memory in its activity.

Very slow and tedious are the degrees with which the perceptive organs become educated and trained to their respective functions; unlike the vegetative organs that commence life and continue it with a perfect adjustment of action, the eye has to be trained to correct vision, the ear to hearing, with the same slowness that the voluntary muscles of the legs are educated to move in unison with the will, and with each other.

The mode in which Memory becomes educated and trained, indicates it to be a physical action dependent on physical organization. The memory in some individuals enables them to acquire easily, but to retain with difficulty: with others, great slowness and difficulty is experienced in order to acquire, but the acquirement once made, the retention is permanent. As muscular dexterity is acquired and perfected by exercise, so is memory strengthened and improved by the same means.

276. *Volition* or *Will* is in order the third cerebral action called into existence. It is not an original faculty born with the individual, like the action of the heart-muscle, but like the voluntary muscles acquires its action as the necessity for it arises. Will may be characterized as an "*effort of attainment*"* born into use by necessity of exertion, and trained to combine with the actions of the external organs of perception. The degree of power that the will attains is in proportion to the *attention* brought to bear upon the effort to attain. To render this clear it must be borne in mind that the human infant comes into the world a mental blank: it has none of the

* Haslem's Lectures.

instinctive intelligencies of the lower animals: every motion of its body is purely involuntary; it has not the slightest manifestation of will. By degrees, as the perceptive organs acquire their functions, and memory advances from its passive state, a desire to attain is feebly manifested, which, increasing as the perceptions become perfected, and language begins to be acquired, the will or "*effort of attainment*" grows by exercise, and becomes in maturity such as the individual becomes;—for the will of each individual is unlike the will of others:—the will of every individual being in fact the result of his corporeal and mental acquirements, and its influence upon the moving powers of the body and the faculties of the mind, is the effect of repeated effort and habitual training.

At this point those mental attributes of animals analogous to those of man find their limit. With them, memory, except in some instances of domesticity and artificial training, is always passive. The will that they possess can never entirely excite the cerebral ganglia that give birth to memory; they have no language, therefore cannot acquire or communicate knowledge, consequently, have no *thought*. Man on the contrary according to the greater or less perfection of his cerebral organic structure, and the training it has received, can at any moment recal the image of the past—the sounds or language heard years before. At this point therefore commences in man the faculty, attribute, or action, peculiar to his brain—*Thought*.

277. From what has been stated of the physical nature of the cerebral actions, perception, memory, and will, actions recognized as purely physical in the lower animals, it will not be difficult to comprehend that *thought* must be the resulting action of a structure superior in its arrangement to the intellectual organization of all other animals.

In the foregone descriptions and comparisons of the intelligent structures of the various grades of the animal kingdom, it was shown that their complexity of formation, and their degrees of intelligence outwardly manifested, bore a greatly corresponding accordance. It was also shown that the human brain, although partaking of the general conformation of the higher vertebrata in those parts which we have reason to believe actuate the lower intellectual faculties, becomes greatly concentrated, augmented, and developed in those portions that are evidently the seat of the higher human intellectual faculties. We should therefore expect from the mere difference of structure that the actions of this structural superiority would greatly surpass those of the preceding lower forms. Great as is the structural superiority, however, it is infinitely surpassed in the relative advance of intelligence or intellectuality.

Thought is an action of the brain that requires the exercise of volition to render it continuous and harmonious: this exercise of the will is *Attention;* and it is a fact felt by all, that without this primary act of volition, thought is ineffective. The physical nature of thought and will is shown in the fact, that the over exercise of the two combined produces a fatigue that, similar to the fatigue experienced by voluntary muscles, can only be relieved by rest; and also that the duration of this exercise is dependent upon training or education.

Thought may be defined to be an *elaboration of the attainments of the intellect.* These attainments are the acquirements of the perceptions retained by the memory—in the aggregate comprehended by the term knowledge; and the medium by which thought originates and its consciousness manifested is language.

In some individuals when thought has been richly supplied by the perceptions with knowledge, a peculiar activity obtains which has been designated *Imagination.*

This modification of thought is distinct from *exuberance of fancy*, incompatible with probability and natural laws. "Imagination is the decoration and ornament of thought, strictly in accordance with the laws of nature and probability."

278. The additional cerebral action, *thought*, with its basis, language, in combination with that of will, memory, and perception, make up that whole, recognized in man as *Reason*.

Reason should be defined, not as an inherent faculty which we possess, but the exercise of several faculties or actions, of which knowledge must be the basis.

Reason is the just and correct estimate of that we have acquired. To this end perception and memory are necessary for the attainment and retention of the given knowledge—language, or its symbols for the process of thought—and *Numbers* for the correct estimate of value.

Language alone is inadequate to the precise definitions of quantity and value. Language may compare; it can state an object to be large or small, near or distant, and thus give a general relation; but is inadequate to define accurately. A definite standard is therefore necessarily required, and this implies numbers.

279. The origin of numbers has occasioned much learned research and disquisition. Of necessity they must have been very limited in their application in the first dawnings of human intellect, but so it must have been with language and all that pertains to the development of the human mind; for it must be remembered that the intellect is a *progressive action* depending upon the acquirement of external knowledge for internal action. Passing by the recondite researches that have elicited that man in his savage and uncivilized state is unable to enumerate beyond the numeral 5, and that the progression therefrom has been compounded of words joined to the integral 5; it will be sufficient to

note that the precision of numbers was a necessity, and that the human intellect arrived at numerical progression in a direct ratio with that necessity.

If we inquire what is the operation of numbers, the answer is definite and certain. However, numbers or rules of arithmetic may be complicated, disguised, or abbreviated, the power of numbers can only consist in additions to existing numbers, or substractions from them, these two operations being all that are within the reach of the human intellect.

Numbers or their representatives, figures, are applied as accurate criteria of quantity, time, space, and value; and these can only exist in the excess or diminution of some definite standard.

Without the conjunction of numbers with language, man could not correctly exercise the faculty termed Reason.

THE PASSIONS.

280. In addition to these mental actions, there are certain feelings and emotions that ordinarily remain dormant, but are manifested with more or less intensity according to the circumstances exciting them, and the temperament of the individual. These have been designated passions. Observation teaches us that animals, especially of higher orders, are actuated by similar feelings, roused into action by the mere animal instincts. The human infant is born without passion; for human passion implies the previous acquirement of perception, with its associate memory, and with a certain degree of volition, and is the display of intelligent feeling—the outward and visible sign of an internal mental impression.

Anger and *Fear* are the earliest manifested. *Jealousy*, *Hatred*, and *Revenge* soon appear; and at the period of puberty *Love*.

These manifestations of feeling or passions, have various degrees of intensity, and, although necessarily mental operations, they bear external corporeal characters of their interior workings. These are especially denoted and exemplified by the expressions of the countenance and by gestures. A sudden burst of anger has been sufficient to produce pain and disease—even apoplexy and death. *Joy*, suddenly and powerfully excited, has produced the same results. *Fear* produces effects the direct opposite of these; the blood forsakes the cheeks, prostration of muscular power ensues, the body becomes colder and motionless; and when the shock of fear is sudden and intense, it suspends the ordinary operations of the intellect.

Love is a passion that arises with puberty, and declines with the decay of the functions of the reproductive organs.

281. There are some mental emotions or feelings that have their outward exponents in Blushing, Weeping, and Laughter.

Blushing is produced by the sudden enlargement of the capillaries and small vessels of the surface, and is opposed to pallor, which is due to a universal contraction of these vessels.

The sudden pouring forth of the lacrymal secretion or tears is a result of a nervous influence uncontrollable in children and some adults, but mostly controllable by an effort of the will to restrain the exudation.

Laughter is an involuntary convulsion or spasm of the diaphragm and muscles of the chest. It indicates two very opposite states, either joy, mirth, or pleasure, or may be the result of disease and madness.

282. These emotions or passions in man arise from the sudden excitation of external circumstances, and their uncontrolled indulgence upon every occasion that gives rise to them, would render him unfit to become a

member of a civilized community. By the exercise of his reason and will, he obtains a mastery over them; and in this subjugated condition they act as wholesome incentives to his actions and intercourse with his fellow-men. This self-control, however, may be carried to a pernicious extent; and the masking the outward exhibition of the present emotion by the assumption of a blank composure constitutes "the nefarious accomplishment"—Hypocrisy.*

283. In all animals, man included, after a certain time has elapsed in which the corporeal and mental functions have undergone a certain amount and duration of action, there occurs a condition in which all voluntary motion is suspended, and this condition is called *Sleep*.

As the vegetative or involuntary functional actions never rest, it follows that sleep only occurs to those portions of the brain, the actions of which are voluntary and intellectual. The sensating organs also are included in the condition of sleep.

The degree of dormancy that occurs is greatly dependent upon the necessity of renovation from intense action. In all action there is consumption and waste of the material of the tissues. As involuntary action is constant, it follows that the amount of force to be accumulated during the term of sleep, or renewal of the tissues, should be equal to the waste of the voluntary and involuntary actions during the waking period. The infant sleeps nearly all its time, the supply of material for growth being required in greater proportion than for waste. The adult man only requires an equilibrium between waste and supply: he sleeps seven, and wakes seventeen hours, consequently he should recover in the seven hours' sleep, the amount of force (repre-

* See Haslem, on the "Intellectual Composition of the Human Mind."

sented by the loss of tissue) wasted by the seventeen hours' action.

Sleep is said to be profound when total unconsciousness is produced; but frequently this unconsciousness is incomplete—mental or cerebral actions take place without the control and supervision of the will;—fantastic images and ideas are produced, and when these are remembered they are termed *Dreams.*

284. *Death* is the cessation of that force, or bond of affinity, which, in the first instance—the cell-formation —produces the self-movement of the inorganic elements. The constant tendency of inorganic atoms is to a state of equilibrium or rest. When vital force is excited and movement commences, the tendency to rest is overcome; but when from any cause,—sudden violence, natural decay of power, or otherwise,—this force is no longer capable of resisting the return to rest, *death* ensues—in the plant, as in the animal.

285. When the several organs of the body, being well developed, perform their functions harmoniously, the individual is said to be in *Health.* In order that this state of the body may be persistent,—and which is the natural state for the body to be in,—it is necessary that the external conditions that surround the individual should be of a nature to conduce to and assure it. The most important of these external conditions—deducible from the foregoing laws governing matter—are, a pure atmosphere; pure water; a sufficiency, without a redundancy of appropriate food; a certain amount of muscular activity; protection from extreme vicissitudes of temperature; with absence of continued intense mental emotion.

While man remains in the savage state, nearly all these requirements of health enter into his condition of existence, consequently the savage generally enjoys nearly perfect health; but as he emerges from bar-

barism to civilization, so do all these elemental constituents of health deteriorate; and ultimately, when the highest state of civilization has been attained, health becomes a rare and difficult corporeal condition to ensure.

The reasons for this appear to be—the impurity of the atmosphere and water, arising from the congregation of many individuals on the same spot. Wealth and poverty—begetting, on the one hand, intemperance in nutrition, and enervating habits of luxurious indulgence; while, on the other, the deprivation of sufficient and wholesome nutriment, habits of uncleanliness; with (in both classes) the constant mental excitement consequent upon the daily cares of civilized existence.

It must also be noted, that once the divarication from the laws of health has been established, and disease—bred, nurtured, and propagated by these several causes—becomes, as it were, naturalized, it is handed down from generation to generation as an inheritance. The formative force that commences the life of the offspring from the germ-cell of the diseased parent, no doubt perpetuates the departure from healthy structure and function, as it perpetuates the facial and corporeal resemblances so frequently seen in the members of whole families. Even in instances where a redundancy of a portion of the body has occurred—an extra finger or toe on the hands and feet, for example—the same monstrosity has recurred for many generations. It is therefore more than probable, that a resemblance in the structure of the unseen organs occurs as frequently as facial resemblance; and thus a natural aptitude for disease commences with the primary formation of the new being.

But although the above conditions of civilization have as yet appeared from their universality to be its inevitable attendants, yet it is not so. It is only ignorance of the laws which govern created matter that produces

these evils in the first instance, and then perpetuates them.

To ignorance, indifference has been added; and it is only of late—almost of yesterday—that attention has been awakened in this country to the fact, that disease and premature death may be greatly prevented by simply attending to and obeying those laws Nature has so legibly impressed upon her works—and not by opposing them, hitherto the rule of conduct of communities as well as of individuals.

INDEX.

THE NUMBERS REFER TO THE PARAGRAPHS.

Acalephæ . . . 210
Acetic acid . . . 193
Acids, vegetable . . 182
Affinity 63
Agriculture . . . 156
Albumen . . . 175
Alcohol . . . 190
Alkaloids, vegetable . 185
Aluminium . . . 90
Ammonium . . . 84
Anatomy, human . . 241
Animalculæ . . . 204
Annulata . . . 217
Antimony . . . 107
Arachnoidea . . . 218
Arsenic 101
Arteries . . . 259
Articulata . . . 202
Asphalte. . . . 195
Asteroids 26
Astral system . . 18
Astræa 26
Atmosphere . . . 69
Attraction, law of . 34
——— chemical . . 63
Azote 68

Barium 86
Beer 189
Bile 253
Birds 221
Bismuth 102
Bitumen 195
Blood 260
Blushing 281
Bodies in space . . 11
Boron 76
Brain 238
Brass 96
Bronze 103

Cadmium. . . . 98
Calcium 88
Camphor 181
Carbon 72
Caseine 268
Ceres 26
Cerium 114
Cell, vegetal . . . 140
——Animal . . . 198
Cellular plant . . . 141
Chemistry, elemental . 41
———vegetable . . 171
Chlorine . . . 71
Chromium . . . 104
Chyle 255
Chymification . . . 252
Cirripedia . . . 214
Coal 128
Cobalt 99
Columbium . . . 113
Comets 32
Constellations . . 11
Copper 103
Coprolites . . . 132
Crust of the Earth . . 41, 118
Crystallization . . 64

Day and Night . . . 36
Death 284
Dinornis 136
Dinotherium 136
Distances of Stars . . 16
Distillation 191
Dodo 136
Dyeing 184

Ear 273
Earth . . . , 23, 36
——heat of . . . 137
Echinodermata. . . 211
Electricity 53
Elements 41
Elliptic 36
Endosmose 158
Entozoa 205
Equator 36
Ether 194
Exosmose 158
Eye 272

Fermentation . . 186
Fertilization . . . 164
Fibrine, vegetable . . 175
Fishes 219
Flame 48
Flora 26
Fluorine 75
Fungi 46

Galaxy 13
Gastric juice . . . 252
Geology 119
Georgium Sidus . . 29
German silver. . . 100
Glands 263
Glass 78
Glucinium 91
Gluten 176
Gold 110
Gravity 34
——specific . . . 44
Gum 177

Health 285
Heart 259
Heat 43
——of the earth . . 137
Hebe 26
Horizon 36
Hydrogen 66

Ichthyosaurus . . 131
Iguanodon 133
Infusoria 204
Iodine 73
Iridium 112
Iris 26
Iron 97

Juno 26
Jupiter 27

Kreosote 195

Labyrinthodon . . 130
Lacteals 256
Lantanum 114
Laughter 281
Lead 106
Leaves 150
Light 49
Lime 88
Lithium 85
Liver 253
Lymph 257

Magnesium 89
Magnetism 54
Magnitudes of Stars . . 11
Malt 158
Mammalia 220
Mammoth 136
Man 230
Manganese 95
Mariner's compass . . 54
Mars 25
Mastodon 136
Matter, definitions . . 1
Matter vitalized . . . 138

Megalosaurus . . . 133
Megatherium 136
Memory 275
Mercury (planet) . . 21
———element . . 108
Meteors 33
Milky way 13
Mollusca . . 201, 216
Moon 24
Motion, law of . . . 35
Muscles 249

NAPHTHA 195
Nebulæ 17
Neptune 30
Nervous system . . 235
Nickel 100
Night and day . . 36
Nitrogen 68
Numbers 279
Nutrition, vegetal . 147, 152
———— animal . . 231
———— human . . 268

OIL, vegetable . . 179
Ores 82
Organs of sensation . . 270
—— of animal nutrition . 250
—— of vegetal nutrition . 149
—— of animal reproduction . . . 233
—— of vegetal reproduction . . . 160
Osmium 112
Oxygen 65

PALLADIUM 112
Pallas 26
Pancreas 254
Passions 280
Petroleum 195
Phosphorus 79
Photography 109
Pith 149
Planets 20
Platinum 111
Plesiosaurus . . . 131
Polypia 152
Potassium 83
Prussian blue . . . 97
Pterodactyl . . . 133

QUADRUMANA . . . 229

RADIATA 200
Reason 278
Refraction 50
Reproduction, animal . 233
————vegetal 147, 161
————human . 234
Reptiles 220
Resin 174
Rhodium 112
Roots 148

SAP 159
Satellites of Jupiter . . 27
—— of Neptune . . . 30
—— of Georgium Sidus . 29
—— of Saturn . . . 28
Saturn 28
Sea nettles 210
Selenium 80
Sensation 270
Shooting Stars . . 33
Silicon 78
Silver 109
—— German . . . 100
Skeleton 249
Skin 267
Sleep 283
Smalt 99
Smell 271
Sodium 84
Solar system . . . 20
———— formation of . 117
Specific gravity . . . 44
Spleen 266
Starch 172
Steel 97
Stem 149
Strata, primitive . . 120
Strontium 87
Sugar 173

Sulphur 77
Sun 19
Systems of stars or suns . 18

Tar 195
Tellurium 81
Thermometer . . . 47
Thorium 94
Thought 277
Tides 39
Tin 105
Titanium. 113
Tongue 251
Touch 267
Tungsten 113
Tutenag 96

Uranium 113
Urea 265

Vanadium 113
Veins 259
Venus 22
Vertebrata 203
Vesta 26
Volition 276

Water 67
Wax 276
Weeping 281
Will 276

Yttrium 92

Zinc 96
Zirconium 93
Zodiac 12

THE END.

BRADBURY AND EVANS, PRINTERS, WHITEFRIARS.